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CONTENTS

		Page
G. Wrigley	*Advances in the Use of Agricultural Chemicals in Tropical Agriculture*	271
A. E. Charles	*Selection and Breeding of the Coconut Palm*	283
R. M. Bredon and C. R. Horrell	*The Chemical Composition and Nutritive Value of Some Common Grasses in Uganda—I. General Pattern of Behaviour of Grasses*	297
M. H. Butterworth	*Studies on Pangola Grass at I.C.T.A., Trinidad—III. Concentrate Feeding for Dairy Cows on Pangola Grass Pastures*	305
W. H. Foster and E. J. Mundy	*Forage Species in Northern Nigeria*	311
J. Armour, R. P. Lee and J. G. Ross	*Observations on a Cross Breeding Experiment with Cattle in Nigeria*	319
J. Bowden	*Responses of Cocoa to Copper Sprays in Ghana*	325
T. H. R. Hall	*A Note on the Pruning of Amazon Cocoa in Ghana*	333
R. C. Bullock and F. S. Roberts	Platynota rostrana (*Walker*): *A Peel-feeding Pest of Bananas*	337
D. S. Meredith	*Speckling of Banana Fruits in Central America Caused by* Deightoniella torulosa (*Syd.*) *Ellis*	343
Book Reviews		347
Notes to Contributors		359
Recent Publications		362

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Advances in the Use of Agricultural Chemicals in Tropical Agriculture

G. Wrigley

Fisons Pest Control Ltd, Harston, Cambridge, England

An address given to the I.C.T.A. Association on 21 July 1961 at Uganda House, London

INTRODUCTION

When this talk was first discussed by the Committee, it obviously was impossible, in the 40 minutes at my disposal, to deal with the whole field of application of agricultural chemicals to tropical agriculture, or even to deal with all the major contributions that agricultural chemicals have made to increase production in the tropics. It was therefore agreed to select one example each from the field of insecticides, fungicides, herbicides and fertilizers. I will not deal with what has probably been the most outstanding development in peasant tropical agriculture, the use of benzene hexachloride (BHC) and copper fungicides in cocoa in West Africa, as this will, no doubt, be fully dealt with at the Cocoa Conference later this year.

I have chosen examples from the Caribbean, Africa, South India and Ceylon, and the fourth example from the Far East. Three of my four examples relate to perennial crops, and most of what I have to say is really in relation to plantation cropping. This is largely because perennial crops and plantation systems of management, with their higher yields, are in a much better position to make full benefit of crop protection measures and the use of fertilizers than peasant grown annual crops which, on the whole, have a low cash value, and whose yield can be increased considerably by better methods of culture.

SIGATOKA CONTROL

The first example I have taken is the control of Sigatoka disease in bananas. Sigatoka disease or leaf-spot (*Mycosphaerella musicola* (Leach) or *Cercospora musae*, the conidial stage) did not arrive in the Old World until the 1930s. The first record in the Caribbean area was in 1933, the disease being more or less simultaneously noted in Surinam and Trinidad. In 1935, there was a serious attack in the banana plantations of Honduras, which destroyed 22 000 acres of bananas. Production in Honduras, which had reached 27 million stems in 1930, was cut by half in 1935, and by 1940 production was down to 5 million stems, largely on account of Sigatoka disease. The same occurred in Mexico, whilst in Cuba, the banana industry was all but destroyed. The warm, humid conditions of the Caribbean area were highly conducive to the rapid spread of this disease and the position was critical. By the middle of 1936, however, after a series of trials, Dunlap

developed a method of control, using 200 to 250 gallons per acre of 5–5–50 Bordeaux mixture, applied fortnightly or monthly, depending on the weather.

For the next 20 years, bananas in Central America and Jamaica were regularly sprayed with Bordeaux mixture to keep Sigatoka within limits. 'Fixed' coppers were tried at intervals, but they were never completely satisfactory. By the middle of the 1950s, the United Fruit Company alone was spending over £7 million a year on the application of Bordeaux in their banana plantations. During the 20 years of Bordeaux spraying, the only real progress that was made was the inclusion of wetting and spreading agents, which improved the efficiency of the mixture and enabled better coverage to be obtained. Other additives were developed which enabled spraying to be carried out on rainy days (RADLER, 1959).

The first major advance occurred in the 1950s, when GUYOT (1953) with CUILLE (1954, 1955) discovered that the application of 4 gallons per acre of oil, incorporating a copper fungicide gave excellent control of Sigatoka. Subsequent work showed that the amount of oil could be reduced by half, and in addition, it was not necessary to incorporate the fungicide. The oil alone was acting as an eradicant and arresting the infections in an early stage (CALPOUZOS *et al.*, 1959; KLEIN, 1960). Subsequent work in Jamaica (LEACH, 1958) confirmed that oil applied either by shoulder-mounted low volume knapsack sprayers or by aircraft, gave an excellent control of Sigatoka and the volume of oil was gradually reduced until only ¾ gallon of oil per acre was sufficient to keep the disease well under control with normal levels of infection, up to 1½ gallons/acre being required for peak infection periods. The cost of spraying to a large organization like the United Fruit Company, on conversion to oil, was reduced by about half to a quarter, compared with the high volume Bordeaux spraying. In addition, spraying gangs, which were becoming more difficult to find, were no longer needed and supervision was eliminated.

In the very high-yielding areas of Central America, however, it was not long before doubts were raised about the advisability of continuing with oil spraying. No adequate yield trials had been carried out, comparing the Bordeaux treatment with the new oil protective measures, but the experienced plantation managers were convinced that yields were being reduced by approximately 10 per cent by the continued use of oil. The position was further complicated by the rapid upsurge in wet areas of caterpillars, of which *Ceramidia*, *Orsiphanes* and *Caligo* spp. were the more important. These caterpillars could destroy the foliage of large areas of banana plantations in the course of a few days. The reasons for this population increase have never been adequately explained, but it was probably due to a combination of a natural upsurge in population, believed to be cyclic, and the abandonment of Bordeaux spraying, whose deposit was unpalatable to caterpillars. It is also quite possible that the oil was having an ovicidal effect on the eggs of the predators of these caterpillars. Despite the low cost of oil spraying, the United Fruit Company rapidly began to put back Divisions to ground spraying of Bordeaux and carried out more elaborate tests to study the effect of the oil spraying. Oil spraying appeared to slow down the growth of the banana plant and reduce the number of

functional leaves. These leaves were more easily damaged by the wind. It was also suggested that oil might be interfering with the stomatal movement, preventing the plant from controlling transpiration. A loss in the yield was also recorded in the Cameroons (PRICE, 1960), but it is generally believed that the losses from oil spraying are most severe in the higher producing areas growing ' Gros Michel ', rather than the lower yielding areas of the West Indian Islands, planted to ' Lacatan '.

The economic attractiveness of aerial spraying for the control of Sigatoka led to an investigation of the factors responsible for the effectiveness of Bordeaux in an effort to obtain an aerial spray which would have the fungicidal properties of Bordeaux mixture without the phytotoxic or the disadvantageous side effects of the oil. This work has been summarized by EVANS (1961). Studying the deposit of fungicidal wettable powders on the banana leaf, it was observed that the deposit tended to accumulate along the veins, and the interveinal areas received very little fungicide. This was particularly noticeable when large drops were sprayed, but when the droplet size was reduced to the order of about 200 μ diameter, a much more even distribution was observed. If the surface of the banana leaf was rubbed gently with the fingers before spraying, the droplets distributed at random, irrespective of size. Fulton, examining Sigatoka infected banana leaves in Central America, showed that 60 per cent of all the lesions on the leaf were alongside the veins, even though this area only occupied 10 to 20 per cent of the total leaf area, suggesting that the spores were distributed in a manner similar to spray droplets. When a standard wettable powder fungicide is sprayed on to the leaf, it accumulates with the spores, alongside the veins, but 40 per cent of the germinating spores are in the interveinal lamina, which is protected by an inadequate amount of fungicide. Oil arrests all those lesions in the yellow streak stage which appear normally on the first or second true leaves, but will not arrest earlier or later infections (CALPOUZOS *et al.*, 1959; KLEIN, 1960). Standard wettable powders control those spores alongside the veins, but Bordeaux, which builds up a deposit all over the leaf, effectively controls the disease over the whole leaf area. The obvious need is a formulation of fungicide sprayable at low volume from aircraft which has the physical characteristics of distributing over the whole leaf area in sufficient amounts to control the disease.

LEACH (1946) described the tip spotting and line spotting symptoms of Sigatoka on the banana leaves. During the course of studies on the deposit of fungicides on the banana leaf, it was shown that, though the main mass of the growing spike or unopened leaf was highly reflective to water or spray droplets, the very tip of the spike was not, and if water droplets containing spores landed here, the typical tip spotting infection described by Leach could develop. Leach explains the line spotting symptoms by the accumulation of water containing spores along the edge of the unfurled leaf. This was confirmed by spraying a fungicide which was highly phytotoxic to the young banana leaf and observing the symptoms on the opened leaf. These corresponded very well with the symptoms described by Leach. A closer examination by Evans of both these spotting patterns showed that they are composed of short lateral lines of lesions, which have a tendency to follow the veins. Yet these young leaves, when sprayed from the air,

do not retain sufficient fungicide of a standard wettable powder to have a protective action, and unless the fungicide acts as an anti-sporulant, the protection would be inadequate. In a very simple test, which has been developed in the United Fruit Company laboratories (EVANS *et al.*, 1961), fungicides can be compared for their anti-sporulant activity. It had already been observed that, when fungicide spraying was introduced to a standing field of established infected bananas, there was a delay before the fungicide produced any significant reduction in the incidence of Sigatoka. Experiments have shown that, in order to obtain adequate protection with a fungicide sprayed from the air, it is necessary to use a persistent fungicide with repeated applications in order to build up a deposit on the older leaves, equal to that given by a high volume ground application. As the middle and lower leaves are the main conidial producing areas of the infected plant, until these are adequately covered with an anti-sporulating chemical, there will be no marked effect from aerial fungicide spraying. This was confirmed in an experiment where the bananas were cut down and the regrowth sprayed. The response in this case was almost immediate, the inoculum potential having been reduced by cutting down the old bananas.

This is a highly important factor when carrying out comparisons of fungicides for the protection of bananas against Sigatoka. Aerial application of protective and anti-sporulating fungicides will not have the maximum effect until after the experiment has been in progress for over six months, and the comparisons of fungicides carried out earlier could lead to very misleading deductions. Similarly, the more resistant the fungicide deposit is to weathering, the more striking the control, as the anti-sporulating deposit will build up to a more effective level. Oil spraying, on the other hand, permits the early symptoms, the yellow spots, to appear, but prevents the development of these spots into streaks and lesions, and thus will show a much more rapid response to treatment, as it acts as an eradicant and arrests the young infections in the early leaves. These early sprayed leaves expand into healthy leaves, which bear the mark of the arrested lesions.

To summarize, where the yield of bananas is high, in certain climates, oil has produced a reduction in yield of a greater market value than the saving made by spraying oil, as compared to ground spraying of Bordeaux. In order to achieve the benefits and economies from aerial spraying, it is necessary to utilize a fungicide with a high anti-sporulant action, formulated in such a manner that it will distribute uniformly over the leaf, and of sufficient tenacity to persist until the initially sprayed leaves are dying on the ground and there is no further possibility of lesions producing conidia. Ascospores are produced on trash and so this mechanism applies mainly to infections by conidia. This in turn will eventually lead to less infection, and in time, less possibility of ascospores being found.

COTTON SPRAYING IN AFRICA

The second development which I should like to deal with is the spraying of cotton in tropical Africa. The introduction of spraying in the Sudan has been very well described by SNOW and TAYLOR (1952). Awareness of the importance of jassid on cotton in the Sudan developed in the 1930s and in

the early 1940s experiments were carried out with Bordeaux mixture in an effort to control this pest. COWLAND (1947) reported an increase in yield of 11 per cent with three applications of Bordeaux applied at fortnightly intervals, from the end of October. In 1944, dichlorodiphenyl trichloroethane (DDT), which at that time was a very new material, was tested for the control of this pest. The results were strikingly superior to Bordeaux, and arrangements were made for larger scale trials in the 1945-46 cotton season. Yield increases varied from 14 to 40 per cent in crops of 1 000 to 1 200 lb of seed cotton per acre, the increased yields coming from the later pickings. In the following season, it was shown that the percentage yield increase was related to the time of spraying and the earlier sprayings, which took place in the last week of October, gave yield increases of 66 per cent over the control. Annual spraying of the cotton crop in the Sudan has since become part of the normal cultural practice. Aircraft spraying, applying volumes of 1 to 2 gallons/acre has replaced the more cumbersome ground machines. In the 1949–50 cotton season, 142 000 acres were sprayed, at a cost which did not exceed £200 000 and the estimated increase in yield was worth £4 to 5 million. From the application of ½ to 1 lb DDT, yields were increased by 600 lb of seed cotton (200 lb lint) (SNOW and TAYLOR, 1952). Since the widespread use of DDT for the control of jassids, other pests have developed in relative importance, and today, cotton spraying in the Sudan is a very complicated business. These pests include the flea beetles, *Podagrica pallida* and *P. puncticollis*, which are particularly severe in seasons when the pre-sowing rains are poor. Flea beetles are easily controlled with DDT but it is necessary to spray for flea beetles before the season for spraying jassids begins. Other pests of importance are thrips, whitefly and aphis, which occur between the end of September and early November. The whitefly (*Bemisia tabaci*) vector of leaf curl, also reaches its peak in October. Aphids have also become important, particularly in the private irrigation schemes, largely due to the fact that the sticky secretion (*asal*—Arabic for ' honey ') which they produce develops a black fungus which discolours the cotton and lowers the grade. Aphids tend to reach a peak between September and early November. Thus, the cotton farmer in the Sudan today may have to contend with the mixed infestations of thrips, jassid, aphids and whitefly, and *Table 1* shows the relative importance of the most commonly used insecticides for the control of these associations in the Sudan. All of these insecticides can be applied by aircraft either alone or together.

Table 1. Relative importance of insecticides for controlling pests in the Sudan

Insecticide	*Thrips*	*Jassid*	*Whitefly*	*Aphis*
DDT	*	*		
Endrin	*	†	*	†
Rogor	†	*	*	*
Meta-systox				*

KEY : * Good control. † Clean-up effect but not persistent.

Most of the cotton now grown in the Sudan under irrigation is sprayed with insecticide about twice during the season, usually by a contractor and mainly by aircraft. With this high-yielding quality cotton, the economics of spraying are sound, and the return to the grower from the increased cotton yield is considerably in excess of the cost of protection.

Spraying rain-grown cotton

The success of cotton spraying in the Sudan prompted a number of other cotton-growing territories in Africa to investigate insecticidal spraying.

In 1955 at Ilonga in Eastern Tanganyika, an experiment was carried out where DDT and BHC were sprayed to run off at weekly intervals to determine the maximum yield potential of cotton at different sowing dates. The main pest was American bollworm (*Heliothis armigera*). The results, in lb of seed cotton per acre, are given in *Table 2*.

Table 2. Effect on cotton yield of DDT + BHC spray at Ilonga, 1955 (Data from Progress Reports *of Experimental Stations, Empire Cotton Growing Corporation)*

Sowing date	*Unsprayed*	*Sprayed*
28 January	1 734	3 177
28 February	475	2 486
28 March	88	1 630

The cost of chemical for the eight treatments was equivalent to about 320 lb of seed cotton, showing a worthwhile return for the labour of spraying.

Results from a similar experiment at Lumeno in Eastern Tanganyika in 1956–57 are shown in *Figure 1*.

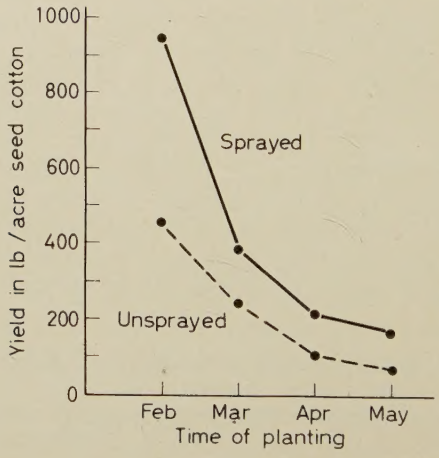

Figure 1. Results of cotton spraying trial at Lumeno, E. Tanganyika, 1956–57 (after Smith, *1958)*

In 1956 at Mokwa, Nigeria, 2½ lb of DDT and 0·7 lb of BHC were sprayed at fortnightly intervals to control stainers and bollworm. The yields in lb per acre of seed cotton are given in *Table 3*.

Table 3. Results of spraying DDT + BHC at Mokwa, Nigeria, 1956 (Data from Progress Reports *of Experimental Stations, Empire Cotton Growing Corporation)*

Sowing date	*Unsprayed*	*Sprayed*		*% increase*
June	455	1 483	(12 *times*)	226
July	371	722	(8 *times*)	95
August	207	241	(4 *times*)	15
September	129	128	(4 *times*)	*Nil*

Again, it will be seen that the benefits from early planting and spraying are considerably greater than from spraying the later crops.

In 1957 in Northern Nigeria, a series of trials was carried out spraying 1 lb DDT plus 0·3 lb of γ-BHC per acre applied on four occasions between early September and the middle of October. The cost of the insecticide and application was estimated to be £7 10*s* per acre. It was estimated that an increased yield of 350 lb of seed cotton would be necessary to cover this.

However, yield increases do not always result from cotton spraying, as was shown by Dale and Coker (1961). In the season 1958–59, 1 lb DDT as a 45 per cent miscible oil was applied in 8 to 10 gallons of water, four times during the season at 10-day intervals. This was carried out at six centres in the cotton growing area of Uganda, and at three of the centres only was there an increase in yield. This is shown in *Table 4.*

Table 4. Effect of spraying treatment on cotton yield (after Dale *and* Coker, *1961)*

Site	*1958–59*		*Difference due to spraying*	*1953–58 average**
	Sprayed	*Unsprayed*		
Nakabango	1 154	1 210	−56	1 593
Kumi	1 690	948	+742	821
Serere	1 530	975	+555	1 334
Aduku	1 287	1 369	−80	1 268
Ngetta	1 181	611	+570	866
Gulu	792	1 003	−211	917

*Data refer to unsprayed trials except for Serere, where only sprayed trials have been conducted over this period.

The position, therefore, in most of the rain-grown cotton areas in Africa, is that by the application of BHC and DDT, which are safe for peasant cotton growers to use, pests such as lygus, cotton stainers and certain bollworms can be controlled and a large increase in yield can be realized, but it is necessary to use approximately four applications. The increase in yield from spraying late planted cotton (peasant growers normally plant much later than the optimum sowing date) is only equivalent to the increase in yield obtained by earlier planting. It would appear that, for a good cultivator, who was planting at the correct time, thinning and weeding correctly, spraying would be an economic proposition, but for the average run of peasant farmers, at their current level of production, spraying is not economic and it is hardly likely that, if years of extension work have failed to convince them of the benefits of early planting, they will be quick to adopt spraying. The peasant cotton in these areas is not grown in a sufficiently large contiguous acreage to warrant aerial spraying, nor is the

specialized technical advice available during the season to enable the spraying to be done only when necessary and at the optimum time, which is the feature of the Sudan.

Unless careful technical advice is available, the use of the wrong chemical could give rise to serious outbreaks of a pest previously unimportant, such as aphids (this has happened in Tanganyika) or spider-mites.

So far in Africa no insect resistance has been shown, but already in the U.S.A., bollweevil, leaf hopper, and cotton lygus are resistant to chlorinated hydrocarbons and spider-mites to phosphorus insecticides.

WEED PREVENTION

The discovery of the herbicides 4-chloro-2-methylphenoxyacetic acid (MCPA) and 2,4-dichlorophenoxyacetic acid (2,4-D), which proved of such profound value to cereal growers in temperate regions, made little or no impact on tropical agriculture. The peasant, who is powerless against an invasion of insects or an epidemic caused by a fungus, can organize his family labour force and deal with the weed problem in his crop if he so wishes. Thus, the development of herbicides for tropical agriculture depended, and still does, on the introduction of a herbicide which could achieve something which hand labour could not, such as the removal of red rice from a paddy field; or it depended upon offering a service to plantation agriculture. This service either had to be a saving in the cost of weeding, or alternatively, in those areas where labour was short, to achieve weed-free crops with the labour available. Weed growth corresponds with the tropical rainy season, the season of heavy labour requirements for planting and, in the case of tea, harvesting. The early herbicides which were tested did a good job in destroying the standing vegetation, but under the hot humid conditions, the regrowth was rapid and within a matter of weeks, the situation was as bad as before spraying. In the last two or three years, experiments have been in progress throughout the tropics, particularly in the plantation crops, on a new concept in weeding, that is weed prevention, not week eradication. This has followed the discovery and introduction of the persistent herbicides of the phenyl urea types, such as monuron and diuron, and the triazine herbicides, simazine and atrazine. Both these groups of herbicides are relatively insoluble and stay in the top-soil after spraying. They are slowly broken down by microbiological activity in the soil and it is also probable that certain soils such as clays and humus soils have the property of adsorbing them on to the colloidal particles. This loss is a relatively slow process, and even under tropical conditions, a low dosage rate can prevent weed growth for up to six months. In Brazil, for example (MEDCALF *et al.*, 1961) it is estimated that about a quarter of a million workers are employed in hand hoeing coffee. Such labour could be better utilized in harvesting, which is still, in general, very badly done, enabling a better quality coffee to be produced. Medcalf *et al.* estimated that, including the labour for hand weeding prior to spraying, the use of these persistent herbicides for the prevention of weed growth along the coffee planting rows cost approximately 10*s* per hundred coffee trees. MEDCALF and DE VITA (1959) had already shown that these herbicides could be of considerable value in preventing weed growth before the harvest of the coffee. A problem similar to the

coffee harvesting in Brazil occurs in oil palms. In order to determine when the bunches are ripe, it is necessary to watch for the odd fruit falling. If there is a dense growth of weeds in the palm circles, this is difficult and the superintendents must observe the bunches on the palms to determine when they are ready for harvesting. If the palm circles are cleaned up either by hand hoeing or the application of a herbicide such as sodium chlorate or sodium arsenite, or a mixture of translocated herbicides which will detsroy all the vegetation, and this is followed by the application of a persistent herbicide, the palm circles can be kept free from weeds for long periods and enable the harvesting operation to be carried out both more efficiently and with less inconvenience to the labour. This has been described recently by KAVANAGH (1961). Weed prevention with persistent herbicides also shows considerable promise in the prevention of weed growth in oil palm and rubber nurseries. It requires considerable labour to keep these nurseries free from weeds and much damage can be done to the seedlings if the weeding is carried out in a careless fashion.

Since 1945 there has been an intensive programme of re-planting of rubber in Malaya. The recommended sytem is to plant the trees along the contour, and between the rows of trees, cover crops are sown. The planting rows are maintained in a weed-free condition by constant hoeing. At the start of the rainy season, the planter may wish to use the maximum labour force on his replanting programme, as if this is delayed, the percentage of plants which take may be disappointing. If he withdraws the weeding force and uses them for planting or other operations, the weed growth rapidly gets out of hand. In the past, it has been possible to clean up the planting rows with a spray of sodium arsenite, but from September 1961 this will not be permitted. The Rubber Research Institute of Malaya has done a great deal of work on the control of weed growth by a mixture of amino-triazole and dalapon, but more recently experiments have been carried out with a new material, paraquat, which is a dipyridyl quaternary salt. This material, when sprayed on standing weeds, gives a very dramatic effect, the whole of the sprayed area turning black and dying within a few days. It has, however, no persistence, being broken down immediately on contact with the soil, but it is possible that it may be combined in use with one of the persistent herbicides to give a combined destruction of weeds along the planting rows, together with weed prevention. This would enable the rubber planter to spray his planting rows and then turn his attention to the other field operations.

Similarly, in the tea areas of Ceylon, some planters have been cleaning up the tea, particularly after pruning, by spraying with simazine, which prevents recolonization for a few months. In view of the steep hillsides on which the tea is grown, it is perhaps fortunate that the weed *Oxalis* survives the hoeing and spraying and remains to bind the soil and prevent further erosion (MEDLEY, 1961).

The advantages to the planter who introduces these methods of weed prevention are not only that they prevent the weeds competing with the crop for nutrients, air and water, but they also reduce the amount of damage which is done to the surface roots each time the labour force go through the crop to hoe the top-soil. It is a very common sight in either tea or

rubber plantations to see the roots exposed by this continual hoeing, and it is difficult to believe that this can do anything but harm. The use of these herbicides with persistent activity also enables the planter to handle the peak labour demands without employing additional labour which, in certain countries, is today not very easy to dispense with after the need has gone. The final decision will depend on whether the planter can show in his balance sheet that by this new method he is running his plantation more economically. It should be pointed out that in all these crops, before wide-scale use is introduced or recommended, the toxicity of the persistent herbicides to the crops is studied both in the field and in pot trials. In addition, samples of the soil of sprayed plots taken at different levels are analysed over a period of time in order to study the rate of breakdown of the herbicide under tropical conditions, to ensure that by repeated application, the herbicide is not being built up to toxic proportions. In this connection, MEDCALF *et al.* (1961) quote a case where in 1957, several six-month old coffee trees were accidentally treated in the field with 50 lb per acre active ingredient of simazine, which was ten times the maximum single dosage being used in the experiments. The foliage of the seedlings became quite chlorotic and the growth was retarded for 8 to 10 months, but all the trees eventually recovered and made normal growth. Similar trials have been carried out on other tropical crops and the tolerance rates of the crops to these persistent weed preventatives have been determined for the herbicides in use.

POTASSIUM REQUIREMENT OF TEA

There is a general agreement today that to support the rapidly increasing population of the tropics, the increased use of fertilizers is a major necessity. A study of the many results published on fertilizer trials gives a confusing picture, not only between territories, but for studies on a single element in the same territory, with, of course, a few notable exceptions, such as the marked response to phosphate in Northern Nigeria. There are many factors, such as rainfall, placement and interaction between nutrients, that account for many of the variations. But in the light of experience with potash fertilizers in tea in South India and Ceylon, it is possible that the fertilizer treatment experiments are not continued for a sufficiently long time. In 1930 the Tea Research Institute of Ceylon laid out at St Coombs Estate a nitrogen–phosphorus–potassium trial. By 1940 only nitrogen had shown any marked effect. The experiment was on a three-year pruning cycle and it was not until the fourth pruning cycle, which ran from 1940–43, that the first symptoms of potash deficiency became visible on the plots. The importance of this element increased so rapidly that potash became the major factor in determining the yield. 40 lb of potash per acre gave a yield increment of 497 lb of manufactured tea per acre compared with an increase of 395 lb of made tea from a dressing of 80 lb of nitrogen (PORTSMOUTH, 1949). About the time that this experiment was beginning to show the effects of potash deficiency, the United Planters' Association of South India laid down a similar experiment. In this case, the lack of potash in the fertilizer mixture became apparent in the eighth year, but the experiment eventually had to be abandoned, as the plots where no potash had been

applied had lost so many bushes as to invalidate any statistical treatment (JAYARAMAN and DE JONG, 1955). This is in very sharp contrast to the remarkable response to potash which was recorded in an experiment in West Africa. There, the application of a single treatment of potash fertilizer to oil palms had a residual effect on the crop for the following six years (CHAPAS and BULL, 1956).

SUMMARY

To summarize, I hope that the examples that I have chosen will illustrate that the advances in the use of agricultural chemicals in tropical agriculture have not and will not come from taking down a bottle from the shelf and applying it at random over a crop. The whole development is the integration of the knowledge of the planter, the chemist, the physicist and the biologist. It must never be forgotten that the crop plant is really the important factor in the whole operation, and it will always pay to study the plant and the way in which the crop pest, or disease, or nutrient deficiency, is affecting it. Laboratory studies either biological or analytical may be necessary to supplement field observations. The example in relation to potash illustrates that it is not sufficient to carry out an experiment over one year, and if nothing happens to abandon the idea and search for a new one. Persistence and long term experimentation may throw up important results. The final answer, however, lies with the tropical farmer, who will not adopt any measure until he is certain that it is to his benefit, particularly financially, to do this. Agricultural chemicals do not solve the inefficient farmer's problems, but they enable the good farmer to reap a greater reward for his efforts. The experiments in the rain-grown cotton areas of Africa have shown that early planting gives marked increases in yield. Spray trials carried out show that often a combination of early planting and spraying gives a final yield greater than anyone would have anticipated was possible under such conditions (2 000 lb per acre of seed cotton has been harvested at Samaru in Nigeria, without irrigation).

We are only at the start of the development of the use of agricultural chemicals in tropical agriculture and the next few years will undoubtedly show what can be achieved by the intelligent application of science to agriculture. This must be achieved if the peoples of the tropical world are to survive.

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Selection and Breeding of the Coconut Palm

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Basic research into methods of improving production in the coconut palm (*Cocos nucifera* L.) has probably been more neglected than in any other crop of comparable importance. One of the most striking features of the recent review of coconut breeding by Gangolly, Satyabalan and Pandalai (1957a) is the dearth of soundly based experimental data which they were able to quote. Some of the reasons for this are obvious to anyone who has worked with the crop—the difficulty of access to the flowers of the mature palm, the long generation period, the apparent impossibility of clonal reproduction and the large areas of land required for multiplication. In addition, the crop is grown mainly in relatively underdeveloped countries, where lack of both finance and trained personnel has limited research. Most systematic research on the crop has been commenced only within the past thirty years, and throughout Malaysia, the Pacific Islands and Indonesia, the greater part of the initial work was disrupted completely by war, a disruption from which recovery is only now getting under way.

As a result, breeding work with coconuts is still largely in the pioneering stages and any breeding programme has to be based on theoretical principles rather than on practical experience. The programme must inevitably be on a limited scale only, because of the small number of palms which can be handled. It is therefore of the greatest importance that the theoretical principles be sound and that those experimental results which are available be correctly interpreted. It is also most desirable that experiments should be designed and conducted in such a way as to provide a maximum of concrete information about the inheritance of economic characters.

The present paper aims to present a critical review of past results in this field and to recommend a practical approach to future work, especially for Papua–New Guinea. While such a recommendation should be fairly widely applicable, there are two respects in which it may need modification for other countries. First, certain methods which will be discounted as impracticable (e.g. large scale hand pollinations) may be quite practicable where labour conditions are different. Secondly, where, as in many countries, there are serious diseases of the coconut, the breeding of high yielding strains would be of little value unless satisfactory disease control measures could be developed. This might be accomplished through the introduction or breeding of resistant varieties if a suitable source of resistance could be found, but the emphasis of the breeding programme would then be different from that recommended in this paper.

Here it is assumed that the primary aim of coconut breeding is to increase yields of copra. It has been shown that there is little variation in oil content of copra from different palms (CHILD, 1950; TAMMES, 1955), so that there seems to be little scope for breeding for higher oil content. Moreover, the product is usually sold as copra, with no reference to oil content. Development of uniform nut size and shape is of no importance with present harvesting methods, although an increase in nut size might reduce production costs slightly. Certain other characters will be mentioned briefly in the section on selection.

FLORAL BIOLOGY

Propagation of the coconut is exclusively by seed. Vegetative reproduction is probably impossible in a plant which produces only a single growing point (personal observation indicates that the frequency of branching in coconuts is less than one in a million). HARLAND (1957) has recommended the investigation of possible means of vegetative reproduction, such as hormone treatments to induce adventitious budding, but the possibilities seem remote. Moreover, it is difficult to envisage vegetative reproduction being simple enough to be used on a large scale, and we may assume that commercial propagation will continue to be by seed.

The first requirement for the breeder is, therefore, to determine whether the plant is self-pollinated or cross-pollinated. Floral biology, as it relates to this question, has been adequately reviewed by PATEL (1938). In the ordinary tall coconut, it is clear that usually cross-pollination is obligatory, since the male and female phases on the same palm do not normally overlap. Rare cases of overlapping occur when the female flowers of an inflorescence become receptive before the last of the male flowers have shed. Less rare is the occurrence of overlapping when the male flowers of a new inflorescence open while the female flowers of the previous inflorescence are still receptive. Patel found that the interval between opening of successive inflorescences is subject to seasonal influence, and where there are marked wet and dry seasons, overlapping of inflorescences is common in part of the year. Thus he calculated that inter-spadix pollination on the same palm would be possible on 22 per cent of inflorescences during the year. However, the actual occurrence of such pollination could be expected to be much less frequent than this. In countries such as Papua-New Guinea, where the seasons are less pronounced, overlapping of inflorescences would be less frequent and self-pollination quite rare. It is certainly safe to conclude that the tall coconut is normally cross-pollinated and to devise a breeding programme accordingly.

In the dwarf coconut, on the other hand, it is usual for the male and female phases of the same inflorescence to overlap so that pollen is being shed throughout the whole period when the female flowers are receptive, and thus self-pollination is almost always possible. That it is, in fact, normal can be shown by planting seed from dwarf palms growing amongst talls. Most of the progeny breed true to the dwarf type.

BREEDING METHODS

(1) *Mother palm selection*

Up to the present time, most recommendations for genetic improvement of the coconut have been based on the selection of high-yielding mother

palms for seed supply (SAMPSON, 1923; MENDIOLA, 1926; COPELAND, 1931; DWYER, 1938; PATEL, 1938; PIERIS, n.d., 1941, 1955; PHILLIS, 1946). Even where complex systems of breeding have been proposed, their effectiveness would be dependent on the effectiveness of the original mother palm selection. This applies to such proposals as the use of isolated seed gardens (LIYANAGE, 1953a; MURRAY, 1953), the production of seed by controlled pollinations (LIYANAGE, 1954), and to a lesser degree the system of 'close-breeding' suggested by DWYER (1938). CHILD (1950) pointed out deficiencies in the selected mother palm approach, but still recommended it as an interim measure pending further experimental results.

The appearance of a plantation of coconuts supports the supposition that selection of mother palms would be of value. There is obvious wide variability in the numbers, shape and size of nuts on different palms. Variation in such characters as the colour of the immature nuts shows that there is considerable genetic variability, as is to be expected in a cross-pollinated plant.

However, when individual palms are observed over a period of years, it is found that many of them are not consistent bearers. A palm may have many nuts at one period and very few twelve months later, and *vice versa*. In some countries this may manifest itself in a tendency to biennial bearing of plantations, but under conditions in most areas of Papua–New Guinea the fluctuations tend to be irregular from palm to palm, so that in a large block of palms they cancel one another out. The yield of a plantation as a whole is usually fairly constant from year to year and even from month to month. This may be explained by the regularity of climate in these areas, with little seasonal change in temperature and usually adequate rainfall to supply the palm's requirements even in the dry season. By contrast, in one area of Papua, where the annual rainfall is only about fifty inches and the dry season quite severe, yields of plantations fluctuate widely from year to year. Here it is probable that moisture conditions exercise an over-riding control which synchronizes the fluctuations in yield of individual palms.

Such fluctuation is of considerable importance for mother palm selection especially where it is irregular from one palm to another. Selection of palms on sight, without continuous yield recording over a period, involves the danger of including as heavy bearers some which would not sustain their high yield and also of rejecting as only moderate bearers some which over a period might prove quite good.

An estimate of the importance of these fluctuations, and of the amount of yield variability from palm to palm within a palm stand, can be obtained by analysing yield records of a number of individual palms. The following data are based on records over three years of nut numbers on 128 palms growing on a uniform alluvial soil. These palms are spaced at thirty feet on the triangle, and are about forty years old. The records were taken in connection with a fertilizer trial, the method being to count, at six monthly intervals, all nuts above about four inches in diameter. These counts were made from the ground with the aid of binoculars.

Considering first the total nut numbers for each palm for the full three

year period, analysis showed that the 5 per cent best palms carried approximately 50 per cent more nuts than the average for the whole block. When the nut numbers at a single count were analysed, the 5 per cent best palms were 70 per cent better than the average for that count. These, of course, correspond to mother palms selected ' on sight ' without a period of yield recording. To test the validity of such selection, the total nut numbers of these palms for the full three years were considered and were found to be only 30 per cent above average. Thus, selection on sight does involve a considerable loss of accuracy, and at least three year records would be necessary to determine the true highest yielders.

So far in this analysis, only numbers of nuts have been considered. When the weight of meat per nut was taken into account, it was found that there was some negative correlation between nut numbers and nut size. The average meat weight of nuts from palms selected as the best on the basis nut counts over three years was 10 per cent below the average for the block as a whole. This would reduce the copra yield of the best palms to about 45 per cent above average.

Thus it would seem that the most optimistic prediction of the improvement to be expected from selection would be of the order of 45 per cent. This amount does not compare very favourably with an estimate of 140 per cent which was obtained in a similar analysis of seedling cacao yield variability, based on yields recorded at the Lowlands Agricultural Experiment Station, Keravat, New Guinea (Bridgland, 1960). The implication is that yield variability between individual coconuts may perhaps be smaller than variability in other genetically mixed perennial crops.

Moreover, to gain this 45 per cent increase, it would clearly be necessary to make controlled crosses between the selected mother palms. This technique could not immediately provide improved seed in commercial quantity, although it could be used for the establishment of an isolated seed garden which would ultimately give ample seed. In the interim, production of seed in quantity would require the selection of a large number of mother palms from which open-pollinated seed could be used. This in turn would necessitate accurate yield recording, over at least three years, of some thousands of palms. This would be laborious and expensive in any country, and quite impracticable in countries such as Papua–New Guinea where the nuts are harvested only after falling to the ground. In practice, in this country, the best that could be done would be the selection, on sight, of palms carrying a heavy crop of nuts. These, as we have calculated, might give yields up to 30 per cent above average. However, under open pollination, the male parents of seed nuts would be equal only to the average of the population. Thus the superiority of the mother palms would be diluted, and the progeny could not be expected to be more than 15 per cent better than the average of the population from which the parent palms were selected.

Considering the long bearing life of the crop, such an improvement would be rated as very well worthwhile, if it were actually obtained. However, the only critical experiment that has been carried out to test the advantage of mother palm selection indicates that the expected improvement in the progeny is not obtained at all.

This experiment was laid down in 1939 by the Ceylon Coconut Research Scheme, and aimed to test the value of both mother palm selection and nursery selection of seedlings. (The results of seedling selection will be discussed in the next section of this paper.) For testing of mother palm selection, seed nuts were divided into three classes: nuts from high-yielding palms, nuts from low-yielding palms, and heap nuts. Detailed results of the experiment were reported by LIYANAGE (1958), and the differences in yield between the groups were found to be non-significant. In fact, strangely enough, the progeny of the low-yielding palms gave the highest yields in both numbers of nuts and weight of copra produced.

The conclusion was drawn by LIYANAGE (1953b) that it is immaterial whether seed nuts are collected from individual high-yielding mother palms, or from high-yielding blocks. But it is equally valid to conclude that it is immaterial whether they are collected from low-yielding palms—in fact it seems to be immaterial what sort of palms are the parents. Furthermore, without some external evidence that the superiority of the high-yeilding blocks could be genetic (as, for instance, that the seed had been obtained from a special source), the only reasonable assumption is that they outyield other blocks because of a more favourable soil or other environmental conditions. It is possible that seed nuts from such blocks would have a better-than-average supply of stored nutrients, and would therefore produce healthier seedlings. However, any superiority of the progeny resulting from this would be limited to the first generation and would be of no value for breeding purposes. The superiority would not be genetic. The experimental evidence presented justifies the conclusion that phenotypic selection of mother palms for high yield is ineffective as a means of genetic improvement. This is further confirmed by the finding reported from Ceylon (LIYANAGE, 1958) that in progeny trials there was no correlation between mother palm and daughter palm yields under open pollination.

LIYANAGE (1955) considered the ineffectiveness of mother palm selection to result from the lack of control of the pollen parent, and that this could be overcome by controlled pollinations using high-yielding palms as both mother and father. He advocated the establishment of an isolated seed garden with seed derived from such crosses and such a garden has been commenced in Ceylon. However, HARLAND (1957) has already pointed out that the programme is unsound.

The explanation given by Liyanage for the failure of mother palm selection does not adequately cover the experimental findings. Where, as must have occurred in this experiment, seed nuts were obtained from a number of different mother palms, the pollen would have come from a considerably larger number of palms around them. Differences between these male parents would balance so as to make them, on the average, about equal in yield to the general population. Thus, if mother palms were 30 per cent above average, the progeny should be about 15 per cent above average. Lack of control of the pollen parent would halve the effectiveness of selection of the mother, but it could not entirely eliminate it. It might be expected also that the progeny of the selected low-yielding palms would be half as far below the average yield as were their parents—probably, therefore, at least 15 per cent below average. This would mean that the two extreme

classes in the trial should have been separated by at least 30 per cent. The data given by LIYANAGE (1958) show that the difference needed for significance (in nut numbers) was less than 15 per cent. The inevitable conclusion is that the differences in yield between the classes of parent palms would not be transmitted to their progenies, whatever the mode of pollination.

This means that, in respect of yield, the phenotype of a palm grown under standard commercial conditions is not an accurate indicator of its genotype. In other words, the heritability of yield in the coconut must be very low. This is not surprising in the light of findings with other plants which have been studied more closely. HAYES, IMMER and SMITH (1955) state as a general conclusion to their review of heritability studies that ' the cereal breeder has determined that there is no close correlation between the yield of individually spaced plants and of their progenies under relatively good growing conditions unless a character segregating simply into few easily recognized classes is involved '. If this is true of cereals which can be grown in small plots with fairly uniform environment, it is likely to be even more true of coconuts which occupy such large areas of land. Concerning the modification of the statement in respect of characters segregating simply into a few groups, the authors refer to such characters as disease resistance and any abnormalities affecting yield. Where there are important diseases to which some palms are resistant, selection of mother palms on the ground of disease resistance would always take priority over selection for high yield. There are certain abnormalities in coconuts which affect yield, and which may be highly heritable: e.g. palms which bear only male flowers, palms with unbranched inflorescences, foliage abnormalities, and perhaps the consistent production of a large proportion of ' dumb ' (seedless) fruits. These rarely occur as more than a fraction of one per cent of the population, so are not of major importance. It would, nevertheless, be desirable to cut them out from any block of palms used as a seed source.

HARLAND (1957), after studying the results of the Ceylon experiment described above, gave a similar explanation of the failure of high-yielding mother palms to transmit their high yields to their progenies. He points out that a heavy-bearing palm might owe its high yield to any of the following causes:

(*1*) an unusually favourable environment
(*2*) selection for good vegetative characters in the seedling stage, these being correlated with good adult performance
(*3*) hybrid vigour due to a favourable combination of genes in the heterozygous phase
(*4*) genetical superiority in the form of dominant yield genes.

Only those of the fourth type could be relied on to transmit their superiority to their progeny. Thus, for the general population which includes all four types, yield heritability is low.

The foregoing discussion has been concerned solely with selection for yield. However, there are other characters of some interest, and it is possible that selection for these may be more effective than selection for yield. It is to be expected that some characters would have a higher heritability than others.

Disease resistance—By analogy with findings in other crop plants, it may be expected that where disease resistance is clear-cut, it is probably controlled by a single gene, or not more than two genes. In such cases, selection of resistant parents should give a fair proportion of resistant plants in the progeny. However, if the disease concerned were particularly serious, a controlled hybridization programme would be called for, rather than simple mother palm selection. It should be noted that disease resistance is not always clear-cut and that incidence of disease may be largely under environmental control. This appears to be so with *Pestalotiopsis palmarum* on the coconut, as the disease is usually severe only where the environment is unfavourable for the growth of the palm. Phenotypic selection for resistance to this disease would probably prove just as ineffective as phenotypic selection for yield.

Nut shape—Since the shape of nuts is not likely to be appreciably affected by environment, selection of mother palms producing nuts of good shape should prove fairly effective. However, this character is of very little practical importance within the range of shapes usually encountered. It would certainly not be worthwhile to institute a programme of mother palm selection simply to improve nut shape, particularly as heap nut selection would probably be equally effective.

Husk thickness —This would be of importance where there is a coir industry, but in general the same remarks apply to this character as to nut shape.

Nut size—There is some experimental evidence to support the effectiveness of selection for nut size. In a study of the relationship between characters of seed nuts and of the palms grown from them, LIYANAGE and ABEYWARDENA (1957) found a positive correlation between the size of the seed nut and the size of nuts borne by the grown palm. This correlation held between progenies of different palms, but not within the progenies of single palms (which supports the conclusion that the correlation is due to genetic factors). However, there was also a negative correlation between size of the seed nut and the number of nuts carried by the grown palm, and no correlation with yield. While the amount of material involved in this study was not sufficient for conclusions to be very firm, it does indicate that selection of large seed nuts, while not increasing the yield of the resulting plantation, should give the same yield from a smaller number of nuts. This could lead to some reduction in production costs.

However, since variation in size between nuts from the same palm is much less than variation between nuts from different palms, it is unlikely that mother palm selection would be any more effective than careful heap nut selection. The latter could be much more rigorous, and should therefore prove at least equally effective.

Other characters—PATEL (1938) studied the following characters of mother palms in relation to early germination of seed nuts:

(*1*) high yield
(*2*) high production of female flowers
(*3*) high setting
(*4*) thick meat
(*5*) big size of nuts.

Of these, high setting in particular was associated with early germination.

However, this finding was based on only 85 nuts, too small a number for a firm conclusion to be drawn. Moreover, selection for this character would be possible only where the palms are climbed regularly. Furthermore, as will be discussed later, early germination need not necessarily be associated with genetic superiority.

BONDAR (1939) recommended the selection of palms with forty to fifty branches in the spadix and four to seven female flowers per branch. While such very high production of female flowers may be highly heritable, personal observations in Papua–New Guinea show that this can be a most undesirable character. Palms of this type tend to carry very large numbers of nuts, but these are so small that labourers will not trouble to collect them. While actual copra yield is probably high, it is mostly wasted.

Conclusion—From the above discussion, it is clear that there is no evidence to support the value of individual mother palm selection in coconuts. For the present, all that can be recommended is that seed for planting should be taken from blocks of well-grown, healthy palms, from which any markedly abnormal palms should be removed. Only large nuts of good shape and size should be used.

(2) *Nursery selection of seedlings*

Almost without exception, writers on the subject of coconut plantings have recommended selection of the seedlings in the nursery, for vigour of early growth (SAMPSON, 1923; COPELAND, 1931; DWYER, 1938; PATEL, 1938; PIERIS, n.d., 1941, 1955; PHILLIS, 1946; RAGHAVAN, 1948; EDEN, 1952; LIYANAGE, 1955).

This recommendation can now be supported by convincing experimental evidence. JACK and SANDS (1929) found that in dwarf coconuts, early germination led to early flowering of the palm. This finding was extended to tall coconuts in the trial on mother palm and seedling selection already quoted (LIYANAGE, 1955). Furthermore, in this latter trial, palms grown from selected seedlings have outyielded palms from unselected seedlings in both number of nuts and weight of copra produced. In the first five years, yield was more than 25 per cent higher in the selected group, and after nine years bearing, it was still more than 12 per cent higher.

The following criteria were used in selection:

(*a*) early sprouting
(*b*) vigour of seedling
(*c*) resistance to pests and disease.

It is questionable whether the incidence of pests and diseases in the nursery would be sufficient for selection on this basis to be effective. The effectiveness of selection probably depends mainly on the elimination of less vigorous seedlings. In other words, the underlying principle is early selection amongst the potential producing palms of those which show the greatest vigour. It is only to be expected that these should prove to be the earliest bearers and probably also the highest yielders.

However, while this finding is of great immediate and practical importance, from the long term viewpoint of improving planting material, it is desirable to determine whether this superiority of the selected seedlings is genetic. If it is, then mother palm selection could be effective if based,

not on yield of the mother palm, but simply on its vigour in the seedling stage. For practical purposes, establishment of an isolated seed garden from selected seedlings would then be well worthwhile. In fact, any large plantation established from selected seedlings would serve as a source of superior seed.

It is not possible, on the data at present available, to determine what proportion of the vigour of a seedling is due to genetic factors. The important non-genetic variable here is not the environment within the nursery, since with good management this should be quite uniform from seedling to seedling. However, non-genetic variability in seed from different palms could be quite considerable, since the nutrition of the parent palm would strongly influence the composition and quantity of food reserves in the seed nut. There is evidence also of variation within seed from the same palm which must be of non-genetic origin. PATEL (1938) reported differences in the percentage of total germination and of early germination in seed nuts according to the month of the year when they were harvested. He also reported differences in total germination between nuts from the top or bottom, and from the middle, of the bunch. UMALI (1940) also found differences in seedling growth of nuts from the top, middle and bottom, and also between dorsal and ventral side nuts. It is scarcely conceivable that there could be consistent genetic differences between nuts from different parts of a bunch, or between nuts harvested at different times of the year.

It appears probable, therefore, that at least some of the seedling differences on which selection is based are due to non-genetic factors. It would not be safe at this stage to assume that seedling selection does achieve genetic improvement in the coconut. Thus, the planting of an isolated seed garden from selected seedlings might prove quite profitless. It would be informative to see an accurate comparison of the progenies of the selected and unselected groups grown in the Ceylon trial, preferably with control of the male parent (i.e. controlled pollinations of selected × selected, and unselected × unselected, or else the use of a common male parent for both groups).

Until results of some such experiment are available, the coconut breeder would be well advised to adopt a different approach to genetic improvement. This, however, does not in any way discount the usefulness of the technique of seedling selection for the practical planter, whose interest is in the phenotype rather than the genotype of his palms.

(3) *Varietal testing*

Several varieties of coconuts have been recorded. OMAR (1919) stated that there were fourteen varieties in Singapore, twelve differing in the nut and two also in growth (i.e. dwarf varieties). He quoted WESTER (1918) as saying that the literature seems to indicate the coconut palm to have ' probably no more than thirty five distinct varieties '. Whether these are, in fact, distinct varieties is doubtful—I would incline rather to the opinion of SAMPSON (1923) who speaks of ' many so-called varieties ', it being ' impossible to differentiate between them '. There is unquestionably a clear distinction between the dwarf variety and the tall, which is maintained as a result of the dwarf variety being largely self-pollinated. There

are also several fairly distinct types within the dwarf group, which might be classed as distinct varieties. However, observations in this country indicate that in tall palms, although in any locality there may be different names for different types of nut, these types are not true breeding, and are therefore simply variants within a single, rather heterogeneous, variety.

Nevertheless, Sampson also says, ' Varieties, such as they are, are formed by a large number of trees having the same origin, and therefore being related, being grown in the same locality. This gives a certain amount of uniformity '. Since palms are cross-pollinated, and consequently highly heterozygous, such development of distinct lines could be expected only when all the palms in an area originated from a very few original parents. This may have happened quite often in the distribution of coconuts throughout the many islands of Oceania, and geographical variants might be expected to occur in different localities. In a recent review of the varieties described in the literature (GANGOLLY, SATYABALAN and PANDALAI, 1957b), a large proportion of those listed would appear to be of the nature of geographical variants, since several are named for the localities of their origin.

As an example, the ' Markham ' type coconut in New Guinea may represent such a local variant. In the Markham Valley on the mainland of New Guinea, there are to be found a number of palms in village groves which bear unusually large nuts. Some of these nuts have been planted in other areas and at least a proportion of the progeny have bred true for the large size of nut.

It is probable that some of these local variants would be superior to others in commercial characters, notably in yield. It is impossible to make a valid comparison between them when they are growing under widely differing conditions, but it should be worthwhile to collect them together and compare them in a controlled experiment. This has been commenced for the Territory of Papua–New Guinea in a trial planted at the Lowlands Agricultural Experiment Station, New Guinea. It is hoped that it may bring to light some local strain sufficiently above average in yield to be worth using as a seed source for other areas. There have been found already differences between seed from different sources in the performance of seedlings in the nursery, but it remains to be seen whether these differences will be maintained into adult life.

It would be desirable to extend this type of trial to include seed from different countries. However, at the present time, the existence of a number of unidentified diseases would render such a collection most unwise because of the possibility of disease introduction. It is safer to restrict collection of seed to areas believed to be disease-free within a single territory, and to limit importation from other countries to pollen, which is unlikely to carry disease.

(4) *Progeny testing*

Although trials of the type recommended in the previous section may enable selection of the best local strain, it remains obvious that all such strains are sufficiently heterogeneous for further selection within them to be desirable. Moreover, it is unlikely that a strain which probably originated

purely by chance would be as valuable as one bred from carefully chosen parents.

The problem is to find a method of detecting worthwhile parents. It has been seen that selection of mother palms for high yield is unreliable, and it appears probable that seedling selection is likewise of limited value for genetic improvement.

In many ways, the problems of the coconut breeder are similar to those of the animal breeder, and in some respects more acute. Since vegetative reproduction is impossible, development of a homogeneous variety would require many generations of controlled breeding. The generation length is long, more so for coconuts than for domestic animals. The phenotype is a poor guide to genotype, at least in respect of the most important commercial character, yield. The individual is of fairly high value, so that selection or culling cannot be too rigid and observations must be based on a comparatively small number of individuals. The only appreciable advantages to the coconut breeder are that the individual palm may be used as both male and female parent, and that the individual female parent produces sufficiently large numbers of progeny and is sufficiently long-lived to be worth submitting to progeny testing.

This similarity of problems with animal breeding suggests the use of similar methods, and it is submitted that the most effective approach to genetic improvement of the coconut will be by progeny testing and related techniques. This is the only method that, on present knowledge, can be relied on to detect genetically superior or prepotent palms, and it is therefore an essential starting point for any other breeding system. This method has been advocated already by Child (1950) and by Harland (1957). Child reports that in 1935 progenies of nine mother palms were planted in an unreplicated trial by the Ceylon Coconut Research Scheme. Yield records of these progenies (Liyanage, 1958) indicate probable genetical differences between them. Child (1950) further states that in 1949 a comprehensive progeny test was laid down with seedlings from this trial. Unfortunately this test was later abandoned owing to difficulties in establishment (Liyanage, 1953b). Work was commenced in 1957 on laying down a controlled progeny test of nine mother palms at the Government Plantation, Baibara, Papua. Already there have been found differences between progenies in germination and in certain aspects of seedling growth, but such differences are not necessarily genetic.

Progeny testing could be based quite satisfactorily on the performance of open-pollinated progenies of mother palms. Collection of sufficient seed nuts for an accurate trial would take several months so that seed would come from several different bunches and quite a large number of male parents should be represented. Performance of open-pollinated seed should therefore give a fairly accurate indication of the general combining ability of the palm.

Somewhat more precise results might be obtained by controlled pollination of the mother palms. Use of a single male parent on all palms should make the test more sensitive and might permit a reduction in the number of progeny used. However, this would be open to the criticism that it would test only specific combining ability, and this is not necessarily an

accurate guide to general combining ability. Since crosses between two individual palms could never produce seed in commercial quantity, it is general, not specific, combining ability that needs to be tested. Two methods could be used for very precise testing of general combining ability:

(*1*) Use of several male parents in crosses with all female parents (e.g. ten male parents to produce four or five seed nuts each from each female parent)

(*2*) Testing the parent palms as males, using their pollen in each case on the same female parents.

Both these methods would in theory be somewhat superior to the use of open-pollinated seed, but the practical difficulties would be very great. For the trial commenced in Papua we have been content to use open-pollinated seed.

Progeny testing is a long-term and large-scale project. Results could not be assessed in less than ten years, and indeed yield comparisons could scarcely be finalized in less than fifteen years. It would be undesirable to spread the trial over more than about ten acres, because of soil variability, so that using 50 progeny of each parent, only about ten palms could be tested in one trial. Thus, after fifteen years work one might find only one or two prepotent palms.

Utilization of prepotent palms—Once it had been established that certain palms would give progeny which gave better than average yield, there would remain the problem of their efficient utilization in the production of improved seed.

As has been pointed out above, the number of prepotent palms which could be detected would be small, so their direct use as seed parents would be of no commercial importance. However, they might be used profitably as pollen parents where conditions would permit supply of pollen to planters for use in hand pollinations.

The simplest method of utilization would be in the establishment of an isolated seed garden. Crosses would have to be made by hand between all combinations of the prepotent parents. The seed so obtained would be planted in an isolated block, care being taken to mix the nuts thoroughly so as to minimize inbreeding. Seed from such a garden could be expected to be superior to the average of the general population by about twice as much as were the open-pollinated progenies of the prepotent parents.

Establishment of the seed garden would mean a further delay of ten years in obtaining seed in quantity. In the interim, small quantities of better than average seed could be obtained from the progeny trial itself. As soon as there were clear indications that some progenies were superior (after perhaps ten years), open-pollinated seed from these superior progenies could be used, and could be relied on to be appreciably above average. Later, if a further five years or more of bearing confirmed the earlier conclusions, it might be worthwhile to cut out of the block all the inferior progenies. This should result in some improvement in quality of seed from the remaining palms by giving a measure of control of the male parentage.

(5) *Controlled breeding and hybridization*

The time required to develop a stable variety of coconuts by pure line

breeding would discourage the most ardent, since it certainly could not be achieved within the life of a single worker. However, in institutions where continuity of work on the crop may be anticipated, the possibility should not be overlooked of the utilization of prepotent palms in this way. Selection could be made among the offspring of controlled crosses of prepotent palms for uniformity in desirable heritable characters, such as early maturity, nut size and shape, and perhaps meat thickness. By controlled breeding methods, it might be possible to develop a variety fairly pure in respect of important commercial characters. Considering the reported deleterious effects of inbreeding (TAMMES, 1950) it would be desirable to preserve some variability in non-essential characters, although HARLAND (1957) suggests that the ill effects of inbreeding may not be universal.

Considerable attention has been given to the study of intervarietal hybrids in coconuts (in this sense botanical varieties, as tall and dwarf, are meant)—(MARECHAL, 1928; PATEL, 1938; ANON., 1940; VENKATANARAYANA, 1948; LIYANAGE, 1950, 1958; ANON., 1951; RAO and KOYAMU, 1952; TAMMES, 1955). Most of these workers considered the hybrids promising, and it is suggested that some heterosis operates in wide crosses. Hybrids from the tall and dwarf combination are said to combine the advantages of both—the earlier bearing of the dwarf with the greater vigour and larger nut size of the tall. As proposed by TAMMES (1955) it should be comparatively simple to produce such hybrid seed in commercial quantity by interplanting dwarf palms between lines of tall palms, and emasculating all the dwarf palms as soon as each inflorescence opens. This would ensure that all nuts carried on the dwarf palms would be hybrid. If it is definitely established that heterosis does operate in these hybrids, investigation should be made of the possible benefit of inbreeding the tall parent for a generation. Such inbreeding would be unnecessary for the dwarf palms, which are normally self-pollinated and therefore fairly homozygous.

However, until hybrid and ordinary tall palms have been compared in an accurate replicated trial, the superiority of the hybrids cannot be considered as proven. Hybrid seed would have two disadvantages in that it would be fairly expensive to produce and the hybrid palms when grown would be of no value for seed, since wide segregation could be expected in the next generation. It would therefore be unwise at present to concentrate attention on this type of study to the neglect of progeny testing within the tall variey.

SUMMARY

Experimental and theoretical studies related to coconut breeding are reviewed, and recommendations made for a practical approach to improvement of copra yields. Floral biology is discussed briefly, showing that the tall palm is normally cross-pollinated. The potentiality of mother palm selection is evaluated, but experimental evidence indicates that the technique is ineffective, probably because of low heritability of yield. Nursery selection of seedlings gives improved yields, but the improvement may not be genetic. Geographical variants should be tested for possible value. Progeny testing is recommended as the most reliable method of detecting prepotent palms, and methods of utilization of such palms are discussed. The possible value of hybrid seed requires accurate testing. (*Received November 1960*)

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The Chemical Composition and Nutritive Value of Some Common Grasses in Uganda—I

General Pattern of Behaviour of Grasses

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The total area of Uganda is approximately 60 000 000 acres and of this, there are some 39 000 000 acres available for grazing. The livestock population consists of 3 590 335 cattle, 959 324 sheep and 2 764 635 goats (Department of Veterinary Services and Animal Industry, 1959).

Over large parts of the country the natural grasslands are understocked throughout most of the year. In these areas, the only management practice adopted is the burning off of the grasslands during the dry season which induces a new flush of young grass whenever the next small rain shower occurs.

On the other hand, notably in parts of Buganda, the southern part of Teso District, and the area round Mount Elgon, human and/or cattle populations are very dense. The percentage of cultivated land is high and the ' resting land ' where the grass is communally owned, is severely overgrazed. There is here a need for rational stocking and some form of preservation of fodder resources for the dry season. This would be of immense significance in preventing overgrazing and consequent ' run-down ' of the land.

It is clear that grassland and livestock wealth would become a considerable national asset to Uganda if adequately developed, but much research is necessary.

Work was instituted to study the pattern of seasonal changes and to compare the chemical and nutritive values of some of Uganda's more important grass species, first of all in an unmanaged state and later under various management systems. It is with the first study that this paper is concerned. The chemical composition of unmanaged grasses gives a guide to the nutritional value of undergrazed rangelands; particularly of importance during the dry season when the grazing amounts to very mature ' hay on the root '. In showing the chemical composition/maturity relationship it may also give a guide as to when to cut for hay—a matter of probable concern in the intensive areas in future.

Among the grasses studied, *Brachiaria brizantha* is widespread in some areas where it forms a bottom grass with tall Hyparrhenia species. It also

occurs on disturbed soils along roadsides and under trees. *Brachiaria decumbens* is less widely distributed. Both can be propagated by sets, have a creeping habit, form good swards, are palatable and are good grasses for grazing. They produce very little viable seed, a factor which limits their use for artificial pasture.

Cenchrus ciliaris is indigenous in the semi-arid open grasslands of East Africa. It is a good seeder. The more productive strains are of considerable agricultural value for dry areas and could be used there in leys. It is very drought resistant, and is outstanding also in having better seasonal distribution of growth than many other species. Under good rainfall conditions, it is outyielded by *Panicum maximum* and several others. *Chloris gayana* is not a major grass in natural pastures but due to ease of establishment from seed, has long been used in sown pastures on Government stations. It performs well on soils of medium to good fertility, is palatable and makes a good sward.

Cynodon dactylon contains forms which vary considerably. Some make excellent permanent pasture under particular conditions of soil and climate. The environmental requirements of this species are not well known. Its palatability varies with variety and stage of growth. Cattle tend to graze it mainly in the dry season.

One of the most economically important of the grasses studied is *Hyparrhenia rufa*. This with other Hyparrhenia species is dominant over large areas of natural grazing lands. *Hyparrhenia rufa* is exceedingly palatable despite its habit of producing many hard woody culms (stock ignore these and graze the leaves). It withstands hard conditions including poor soils, drought and overgrazing.

Melinis minutiflora is a constituent of natural grassland at 6 000 ft altitude. It is easily established from seed, but at low altitudes does not stand heavy grazing. It grows luxuriantly in pure stand and two heavy hay cuts per year can be obtained. At medium altitudes, under grazing, it rapidly becomes unproductive and infested with weeds and cannot be recommended for pasture.

Like Hyparrhenia, *Panicum maximum* has considerable economic importance, particularly in Buganda. *Panicum maximum* occurs naturally where soils have been disturbed as along roadsides, and under trees, but is even more widespread on the better soils under good rainfall conditions, in the second year of natural succession after cropping. It is considered to be of good agronomic value and is palatable. It is thought that it will not withstand overgrazing so well as many species. It produces well early in the year, while Hyparrhenia and Chloris tend to flush later.

Setaria sphacelata is widespread over a range of altitudes, on permanent grazing grounds which are burnt annually. In particular it is found on swamp margins and on black cotton soils. Palatability of many varieties found in Uganda is low.

The three species of Hyparrhenia, Chloris and Panicum are all used in leys, in mixture with the legumes *Stylosanthes gracilis* and *Centrosema pubescens*. This practice is recent, and largely limited to the Eastern Province, but it is being introduced into the crop rotation elsewhere in Uganda too, on

Government and semi-government stations and a few private farms. Among the other species, none is sown at present on a commercial scale.

Little work has been done on the improvement of natural stands of these grasses in Uganda. Further information about their varieties and their performance at Serere Experimental Station is given by HORRELL (1958) while much work on them has been carried out at the higher altitude (6 000 ft) Grassland Research Station, Kitale, Kenya (BOGDAN, 1954).

METHODS AND MATERIALS

The grasses were collected from plots which were cut at the end of the dry season. All samples represent undisturbed growth from the beginning of the rains to the time the samples were collected.

With some grasses, sampling was carried out at monthly intervals at Entebbe in 1955 and at Kawanda in 1952–53. Three-monthly sampling was carried out in 1957 at Entebbe, Kawanda and Serere. The period covered by the collections was from the onset of the long rains to the end of the dry season in each case.

Chemical analyses were carried out on a dry matter basis. Samples from Entebbe and Kawanda were oven-dried but samples from Serere were air-dried and drying was completed in the oven.

Digestible proteins were calculated using the equation proposed by GLOVER and FRENCH (1957). The other digestible nutrients were calculated according to WALKER and HEPBURN (1955).

The formulae for digestibility coefficients were as follows:

Crude proteins = 5 + 60 log Crude protein − 0·33 Crude fibre
Ether extract = 9·93 × Ether extract + 33·44
Crude fibre = 107·82 − 1·46 × Crude fibre
Nitrogen-free extract = 1·66 × Nitrogen-free extract − 17·96

Starch equivalent was calculated from digestible nutrients according to KELLNER (1926).

Grasses were investigated as follows:

Kawanda 1952–53 (monthly sampling)

Brachiaria decumbens Stapf.
Cenchrus ciliaris L.
Chloris gayana Kunth.
Melinis minutiflora Beauv.
Panicum maximum Jacq.
Setaria sphacelata Stapf. and C. E. Hubbard.

Entebbe 1954–55 (monthly sampling)

Chloris gayana
Melinis minutiflora
Cynodon dactylon (L.) Pers.

Kawanda is situated at 0° 25′N and 32° 32′E at an altitude of 3 924 ft. The climate is moist and sub-humid. The soil is a reddish brown loam about ten inches deep overlying red clay which is loamy and free draining. The latter extends up to thirty feet below the surface. The soil is of good fertility, moderately acid. It lies within the forest–elephant grass ecological zone (Department of Agriculture, 1959).

Entebbe is situated at 0° 02′N and 30° 26′E, 30 miles southeast from Kawanda at an altitude of 3 770 ft. The climate is moist and humid. The soil is sandy, moderately acid and of poor fertility. It is low in most minerals with the exception of phosphorus and it has a low organic matter content. It lies within the lake-shore ecological zone (Department of Veterinary Services and Animal Industry, 1952 and Department of Agriculture, 1954).

Serere is situated at 1° 32′N, 33° 27′E at an altitude of 3 650 ft. The soil is sandy loam two to three feet deep overlying gravel and ironstone derived from highly sheared quartzite which is lacking in weatherable minerals. It is moderately acid and low in base content and in nitrogen, phosphorus, sulphur and organic matter. It lies in the ' tall grass short tree ' zone where *Hyparrhenia rufa* is the dominant grass (Department of Agriculture, 1959).

RESULTS

The collection of species and strains depended somewhat on their availability in the plots of the three stations. Collections took place over several years.

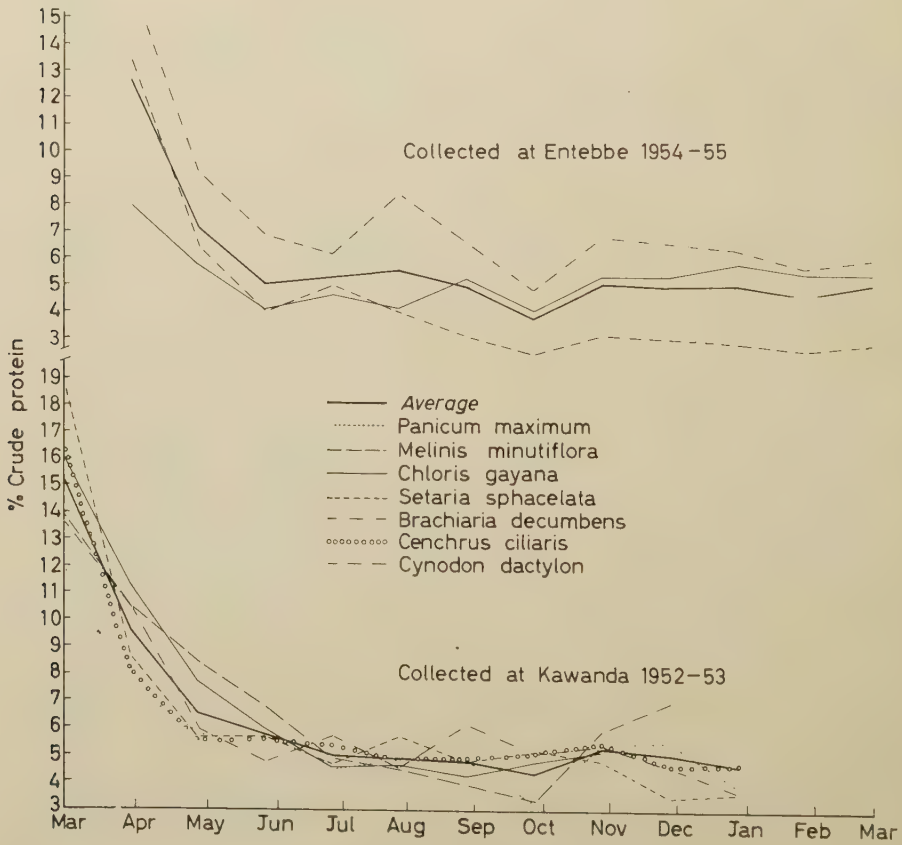

Figure 1. Crude protein contents

To establish the general pattern of changes in chemical composition and nutritive values of grasses throughout the year, monthly sampling of grasses was carried out at Kawanda in 1952–53 and at Entebbe in 1954–55. The results and the pattern of change with maturity of crude protein, crude fibre, nitrogen free extract, starch equivalent and digestible proteins are shown in *Figures 1, 2, 3, 4* and *5* respectively.

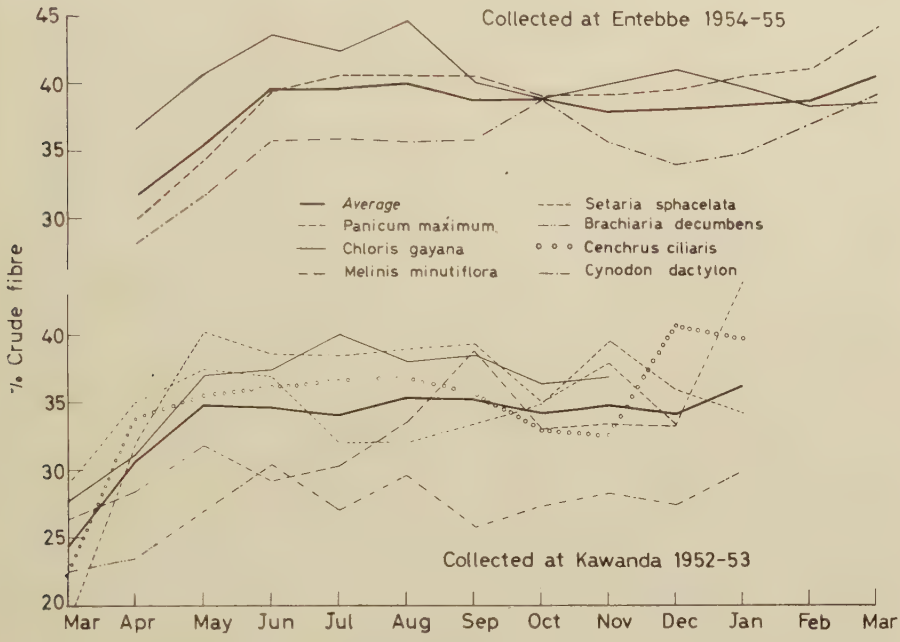

Figure 2. Crude fibre contents

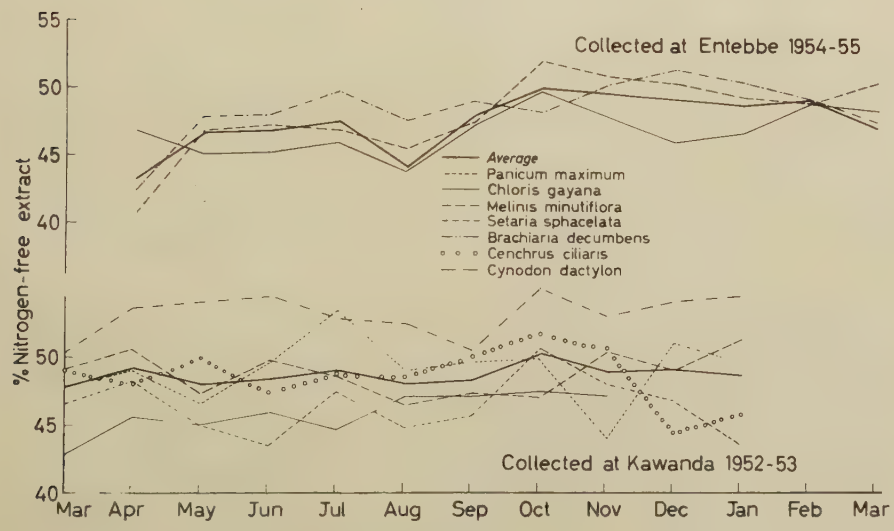

Figure 3. Nitrogen free extract

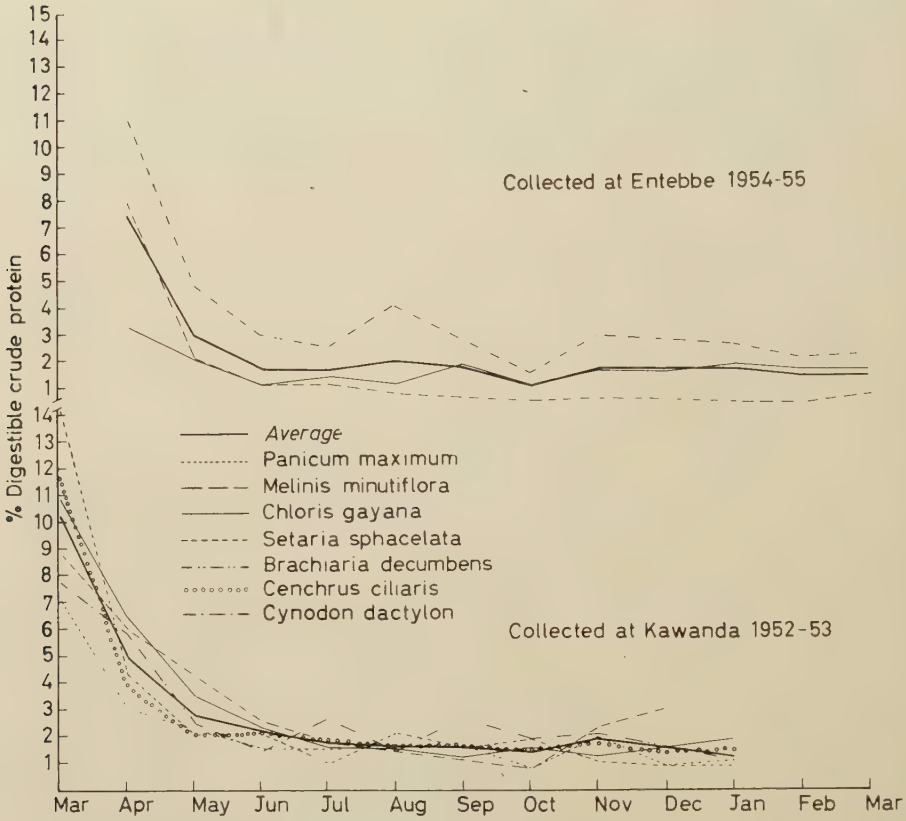

Figure 4. Digestible crude protein

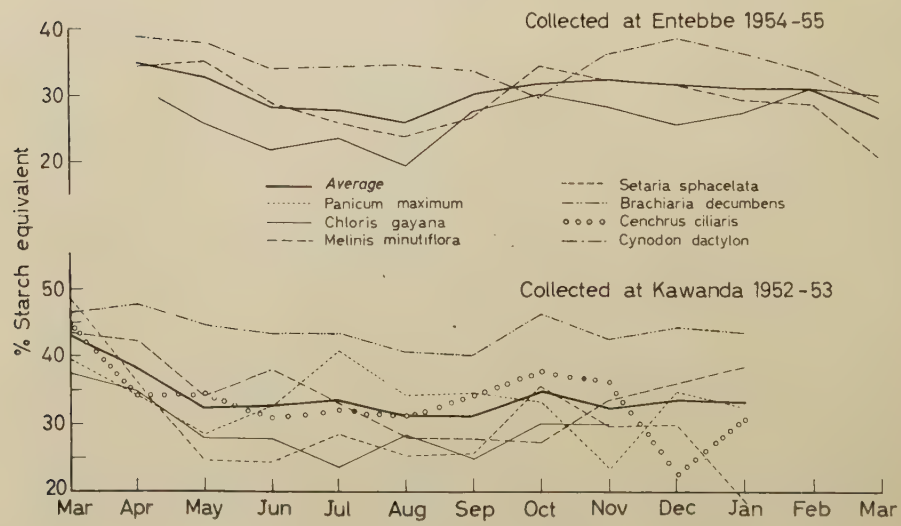

Figure 5. Starch equivalents

It can be seen that the main changes in chemical composition and digestible nutrients occur from the beginning of the rainy season until May, that is, during the first two months of growth.

DISCUSSION

All the grasses show a similar pattern in changes of nutrients in spite of being grown under different soil and climatic conditions, and being sampled in different years. This pattern shows a considerable decrease in the percentage of crude protein and digestible crude protein in the first two months of growth. Thereafter, protein levels fluctuate only slightly, the lowest point for most species being in September or October. During the first two months of growth there is a big increase in percentage of crude fibre; fibre values remain high for the rest of the year. The content of nitrogen-free extract does not change greatly but shows a slight continual increase until the extremity of the dry season is reached. Starch equivalent decreases somewhat during the first two months and thereafter fluctuates only little.

Apart from these general trends, it is clear that there is a considerable difference in the nutritive value of different species, the values for *Setaria sphacelata* being generally on the low side, with *Cynodon dactylon* and *Brachiaria brizantha* higher and *Chloris gayana* between.

There is too a difference between stations; starch equivalent and, to a lesser extent, digestible protein values were higher at Kawanda than at Entebbe. Finally, it is indicated that nutritive values of all the grasses during the first two months of the sampling period more than satisfy requirements for normal growth of cattle, but that values during the rest of the year are very low. These ten months are of great interest as even maintenance of cattle can be a problem at some stages during this time and minor fluctuations in nutritive values of the grasses can be critical. Detailed study of the differences between grass species throughout this period is required.

SUMMARY

A short description of the occurrence and agricultural importance of some common Uganda grasses is given. The chemical composition of grasses grown on two experimental stations was determined. Values of the digestible proteins and starch equivalents were calculated from these results and the broad pattern of their behaviour in chemical and nutritive values was established. The main changes in chemical composition and nutritive values occur during the first two months of growth.

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Studies on Pangola Grass at I.C.T.A., Trinidad—III

Concentrate Feeding for Dairy Cows on Pangola Grass Pastures

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A considerable amount of work has been carried out both in the United Kingdom and elsewhere to determine the contribution made by pasture to the nutrition of the dairy cow. It has been found that in temperate swards, it is usual for the protein content to be in excess of that required for average milk production and, if anything, for the energy fraction to be deficient. Attention has therefore been focused on the supplementation of pasture with low protein energy sources, dried beet pulp having been particularly popular. Results on the whole have been disappointing, increases in milk yield being of a low order (T'Hart, 1956; Corbett and Boyne, 1958; MacLusky, 1955). Various workers have expressed the opinion that supplementation, even though it may allow the full potential of production to be expressed, may not be economic (Riddet and Campbell, 1943; T'Hart, 1956; Paterson, 1954; Corbett and Boyne, 1958).

With tropical pastures it is likely that protein will be deficient rather than energy, but previous work carried out at the Imperial College of Tropical Agriculture on well-managed Pangola grass pastures, has indicated that both from the point of view of energy and protein content (Butterworth, 1961) and of voluntary dry matter consumption (Butterworth, Groom and Wilson, to be published), intake of nutrients from this grass alone is sufficient to support the level of production which is general from cows in Trinidad.

In preliminary work using smaller groups of animals, Onaba (1958) found that concentrate feeding could be drastically cut from a level of 3 lb per gallon of milk without significantly impairing production when cows were grazed on good quality Pangola grass. Two experiments are described in this paper which were intended to extend the observations made by Onaba. The milk production of animals fed concentrates at the high level of 3 lb per gallon was compared with that of animals fed concentrates at a considerably lower level and with the production from cows depending solely on Pangola grass.

METHODS AND MATERIALS

Experimental animals

The animals used in both experiments were chosen from the dairy herd of crossbred Zebu–Holsteins at the Central Experimental Station of the Trinidad and Tobago Department of Agriculture. Groups of beasts balanced for both weekly production and stage of lactation were used.

The average weekly production of both the groups of animals used in the first experiment was 145 lb and that for both the groups of animals used in the second experiment, 147 lb (this level of production was close to the herd average). The average stage of lactation was 27 weeks after calving. In the first experiment 17 animals were used in each group, but in the second experiment the number in each group had to be reduced to 12 because fewer animals were in milk at the time.

Pasture management

The pastures used were the usual ones used by the dairy herd which consisted of good stands of well-fertilized Pangola. The aim of management throughout the trial was to graze the herbage when it contained not less than 10 per cent crude protein expressed on a dry matter basis. The average length of the grazing cycle of the grass was 21 days.

Duration of the experiments

Each experiment lasted four weeks; the treatments were also applied for a preliminary week during which complete records were kept. Records were kept of milk yield throughout each experiment and weekly samples were taken from each cow for butterfat determination (Gerber method, *B.S. 696*: 1955). In addition, weekly samples of the herbage were taken to verify that the content of protein was in fact at or above the 10 per cent level; this proved to be so throughout both experiments.

Concentrate feeding

Animals were brought in for milking twice each day, and at each milking, half of the daily ration of concentrate was offered. The following scales of concentrate feeding were used:

EXPERIMENT I

Low concentrate group.	No supplements were fed for the first 2½ gallons per day and 3 lb of concentrate per gallon thereafter (in fact no animal exceeded a mean daily yield of 2½ gallons so no concentrates were fed to this group).
Concentrate group.	Concentrates were fed at the rate of 3 lb of concentrate for each gallon of milk produced.

EXPERIMENT II

Low concentrate group. Cows in this group were fed according to the following scale:

lb of milk/week	lb of concentrate/day
0–105	0·5
105–140	1·5
141–175	3·0
176–210	4·5
211–245	6·0

This corresponded to a level of 3 lb per gallon above a level of production of 1½ gallons per day. The ½ lb per day was fed to the lower producing cows because it had been noticed in the previous experiment that cows fed no concentrates had been restive during milking and even this low level of feeding sufficed to calm them down and allow 'let down' of milk to proceed normally. Cows in the 'Concentrate group' were fed at the same rate as that used in the first experiment, i.e. 3 lb of concentrate for every gallon of milk produced. The concentrate used had the following composition:

hominy, 11 per cent; rice bran, 25 per cent; citrus meal, 13 per cent; soya bean meal, 8 per cent; coconut meal, 16 per cent; molasses, 13 per cent; limestone, 2 per cent ; salt and other minerals, 1 per cent; high protein concentrate (65 per cent crude protein), 11 per cent. The ration contained 20 per cent crude protein and 72 per cent total digestible nutrients (by calculation).

RESULTS AND DISCUSSION

The results obtained for both milk yield and fat-corrected milk yield of the groups on a weekly basis are set down in *Tables 1* and *2*. Mean values for individual cows have also been included, as have the amounts of concentrates fed to each group. Mean weekly butterfat values are presented in *Tables 3* and *4*.

Table 1. Production of milk and consumption of concentrates of cows fed a high level of concentrates and no concentrates in Experiment I

Week	*No concentrates*			*High concentrates*		
	Milk yield (lb)	*F.C.M.* (4%) (lb)*	*Concentrate (lb)*	*Milk yield (lb)*	*F.C.M. (4%) (lb)*	*Concentrate (lb)*
1	1880	1769	0	2053	1832	609·0
2	1754	1753	0	1935	2179	641·0
3	1869	1884	0	2016	2001	578·0
4	1664	1735	0	2039	2216	641·0
Total	7167	7141	0	8043	8228	2469·0
Mean daily value per cow (17 cows)	15·1	15·0	0	16·9	17·3	5·2

* Fat-corrected milk.

Table 2. Production of milk and consumption of concentrates of cows fed on high and low levels of concentrates in Experiment II

Week	*Low concentrates*			*High concentrates*		
	Milk yield (lb)	*F.C.M. (lb)*	*Concentrate (lb)*	*Milk yield (lb)*	*F.C.M. (lb)*	*Concentrate (lb)*
1	1309	1472	140·0	1355	1511	483·0
2	1211	1330	91·0	1292	1282	472·5
3	1165	1333	98·0	1275	1395	430·5
4	1245	1334	73·5	1328	1260	451·5
Total	4930	5469	402·5	5250	5448	1837·5
Mean daily value per cow (12 cows)	14·7	16·3	1·2	15·6	16·2	5·5

In both experiments yields from the cows on a high level of supplementation were significantly higher than those of cows on the low levels of feeding. In the first experiment, the difference amounted to 1·8 lb of milk per day (11·9 per cent) and in the second experiment, to 0·9 lb (6·1 per cent). However, this increase in milk yield was only made possible by feeding a high level of concentrates. In the first experiment the increase was equivalent to a return of 1 gallon of extra milk from 28 lb of additional concentrates, and in the second experiment to a return of 1 gallon from 17·4 lb of concentrates.

Table 3. Mean weekly butterfat percentages of milk from cows fed a high level of concentrates and no concentrates in Experiment I

Week	*No concentrates*	*High concentrates*
1	3·6	3·5
2	4·1	4·5
3	4·1	4·1
4	4·3	4·6
Mean	4·03	4·18

Table 4. Mean weekly butterfat percentages of milk from cows fed on high and low levels of concentrates in Experiment II

Week	*Low concentrates*	*High concentrates*
1	4·5	4·6
2	4·4	3·9
3	4·6	4·3
4	4·3	3·9
Mean	4·45	4·15

It will be seen from *Table 3* that in Experiment I, the butterfat percentage of the concentrate-fed cows was higher than that of those fed grass alone; this is as would be expected. In the second experiment, however, the butterfat percentages were higher for the cows that were on a lower level of supplementation. This has given rise to the situation where the yields of fat-corrected milk are to all intents and purposes the same. CORBETT and BOYNE (1958) also noted a decrease in butterfat percentage accompanying the feeding of concentrates although this was lower than that observed in the present work. This decrease in butterfat may have been due to a high concentrate ration causing the intake of roughage to be reduced.

No clear reason can be given for the increase in milk production effected by concentrate feeding in view of the evidence already obtained that the intake and nutritive value of the grass were adequate for the level of production reached in the experiment. HANCOCK (1958) as a result of experiments carried out in New Zealand has stated ' that pasture herbage is not a perfect diet for dairy cattle since concentrates are capable of giving a substantial lift in the milk yield when added to an *ad lib.* diet of high quality pasture '. He suggested that this was because dairy cows are capable of consuming some concentrates even after their appetite for herbage is satisfied, and not because of the intake of specific nutrients contained in the concentrates but not in the pasture. It should be stressed that the increases

obtained by HANCOCK (1958) as a result of the feeding of concentrates were considerably higher than those obtained in the present work. The cows used by that author gave higher yields than those used in the present study, and BLAXTER (1958) has stated that ' the higher the lactation yield of the cow when fed according to standard, the greater is her response to additional feed '. It should also be pointed out that estimates obtained by Hancock for intake of dry matter of the cows on pasture alone were considerably lower than the values obtained in earlier experiments carried out at this College. It seems that the contribution made by the herbage to the nutrient requirements of the cows in the present work was higher than that obtained in the New Zealand experiments and that in contrast to the explanation proposed by HANCOCK (1958) for his results, the production of milk by cows fed Pangola grass alone was limited by the intake of some specific nutrient not taken into consideration when the determinations of nutritive value were carried out. No suggestion can be made at this time as to the possible identity of this nutrient.

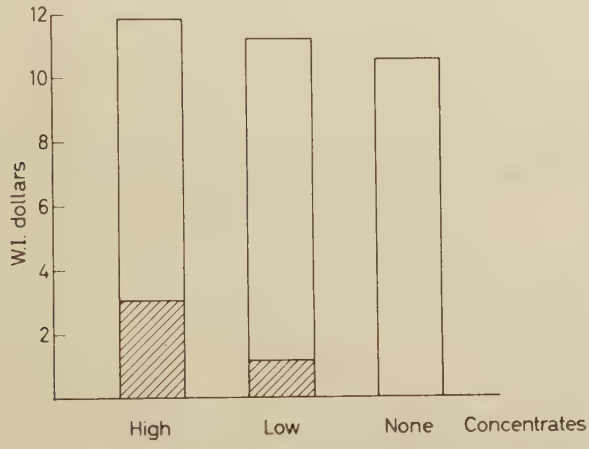

Figure 1. Histograms showing the weekly return from milk sold at one dollar per gallon compared with the amount spent on concentrates at 8½ cents per lb, from groups of cows on three different levels of concentrate feeding. NOTE: *Total columns represent gross returns; shaded portion of columns represents costs of concentrates*

In *Figure 1*, a diagrammatic comparison has been made between the returns obtained by the sale of milk, and the expenditure on concentrates (for the purposes of this comparison, the yields of the low-concentrate group have been adjusted so that the three treatments could be considered together). The price taken for milk is 1 W.I. dollar per gallon, and that for concentrate is 8½ W.I. cents per lb; these are current Trinidad market prices. (NOTE.—One dollar, W.I., is equal to 4*s* 2*d* sterling.) It will be seen that the margin of profit is considerably lower from the group on the high level of concentrate feeding than from either of the other groups. The profit margins from the groups on low levels of concentrates and no concentrates are more similar, although that of the group on the low level of concentrates is somewhat lower than that of the group fed no concentrates

whatever. It is clear that the feeding of concentrates at the higher level is completely uneconomic, whilst the lower level may only occasionally be justified with higher producing animals. If the price obtained for milk were to decrease (as has in fact happened in other parts of the Caribbean) the margin obtained from the concentrate-fed animals would decrease in comparison with that obtained from animals fed no concentrate.

SUMMARY

Two experiments concerned with additional concentrate feeding for dairy cows grazing good quality Pangola grass are described.

The first experiment compared a level of concentrate supplementation of 3 lb per gallon with grass alone. The second compared a level of 3 lb of concentrate per gallon with a lower level of no supplementation for the first $1\frac{1}{2}$ gallons and 3 lb per gallon thereafter.

Higher production resulted from the higher level of concentrate feeding in both experiments. This amounted to 11·9 per cent in the first experiment and 6·1 per cent in the second experiment.

In the first experiment, the group fed a large amount of concentrates gave a higher butterfat percentage (4·18) than the group fed grass alone (4·03). In the second experiment, the lower level of concentrate feeding gave the higher butterfat value (4·45 opposed to 4·15).

It was concluded that supplementary feeding for cows fed *ad lib.* well-managed Pangola grass was uneconomic at the levels of production general in Trinidad.

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Forage Species in Northern Nigeria

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This article presents a summary of the interspecific selection work carried out in Northern Nigeria on forage species. It is now considered that a reasonably complete picture has been built up of the value of most of the commonly used pasture species and to a lesser extent of the fodder species, and also of the more promising indigenous grasses and legumes. At the end of 1959 our Introduction Register listed 266 grass and 244 legume introductions but these totals include varieties and ecotypes within the same species. A list of the more promising and better known species which have been observed in Northern Nigeria is shown in Appendix I.

OBSERVATION PLOTS

Forage species observation records were started in Northern Nigeria in 1945 on plots at Samaru, Lat. 11° 11′N, Long. 7° 35′E. Since then the attempt has been made to establish gardens of small plots in each of the main ecological zones as described by Keay (1959) and also under any specialized environment which is of sufficient importance. A list of the gardens in which records are kept is shown in *Table 1*. In 1961 it is intended

Table 1. List of forage crop observation plot gardens, 1960

Station			*Year of establishment*	*Ecological zone or specialized environment*
Name	*Lat.°N*	*Long.°E*		
Daura	13	8¼	1959	*Browse plants in the Sudan zone*
Katsina	13	7¾	1956	*Sudan zone (rainfall 25–40 in., dry season 8 months)*
Shika	11¼	7½	1952	*Northern Guinea zone (rainfall 40–45 in., dry season 7 months)*
Shika	11¼	7½	1960	'Fadamas' *(a local term for treeless areas bordering a watercourse which are flooded during the rains and maintain a high water table through the year)*
Ilorin	8½	4½	1959	*Southern Guinea zone (rainfall over 45 in., dry season 5½ months)*

that coverage of the country will be completed with the establishment of a garden on the Jos Plateau at an altitude of approximately 4 000 ft.

The normal procedure for the evaluation of a forage species is as follows. After introduction the species is sown in a primary observation plot (10 ft square) usually at Shika and, if sufficient seed is available, in other observation gardens. It is recognized that only a limited amount of information can be obtained from these small plots and their main purposes are the screening of species for adaptation to the climatic conditions and the

classification of the species under one or more of the categories for which material is required. These categories are as follows:

(*1*) Perennial pasture grasses
(*2*) Perennial pasture legumes
(*3*) Grasses, cereals and legumes for use as fodder crops
(*4*) Creeping grasses and similar species for lawns and for use in soil conservation work
(*5*) Browse and hedge plants
(*6*) Legumes for use as green manures.

This primary observation plot work thus provides a limited number of species in each category judged to be worth further study. These species are then investigated in more detail and under a greater range of managemental conditions in large observation plots (usually 0·1 to 1·0 acre in size) or in replicated experiments.

RECORDS

After a period of trial and error a recording and numbering system has been evolved which has proved satisfactory in use and which is described here in some detail.

For each species which is of interest to pasture work in Northern Nigeria a Species Record Card is maintained. This is a 5 in. × 8 in. ruled card on which is collected and condensed all information which is considered relevant to that particular species such as results from observation plots and from experiments in which the species was used, and references to the species in the literature.

Every plant and seed lot received is registered at Shika in the Introduction Register. In this process it receives an Introduction Number which is assigned serially under A for legumes and B for grasses. Any group of plants or quantity of seed which arises from this original introduction (unless by directed selection when it receives a new Introduction Number), is known by a Material Number which is derived as follows. The Introduction Number is followed in parentheses by the number of generations which have elapsed since introduction, followed after an oblique stroke by the last two figures of the relevant year, followed after another oblique stroke by the relevant site. The relevant year in the case of seed is the year of harvest, and in the case of plant material is the year of sowing; the relevant site for seed is the site of harvest and for plant material is the site at which it is growing. An example of a Material Number will make this procedure clear:

A42(3)/59/Katsina O.P.

If this refers to plants they are the third generation plants of the 42nd legume introduction (which by reference to the Introduction Register is found to be an importation of *Calopogonium mucunoides* from Indonesia). They were sown in 1959 and are growing in Katsina observation plots.

If this refers to seed material it is third generation seed of the 42nd legume introduction and was harvested in 1959 from plants growing in Katsina observation plots.

Usually there is no confusion as to whether the material is plant or seed, but in the Stock Book where such confusion may arise a P or S is prefixed to the Material Number.

This numbering system has been found to work well for the interspecific and intervarietal selection work and its complementary seed multiplication and distribution as it summarizes all the necessary information. However, it is not suitable for use in the more advanced single plant selection work where a numbering system founded upon that suggested by NEWELL and TYSDAL (1945) is used.

Looseleaf Stock Books are kept with a sheet for each Introduction Number. These stock sheets which are printed by Moores Modern Methods Ltd to our design and held in their binders are each maintained as a ledger of all plant and seed material bearing that particular Introduction Number. In addition a Seed Distribution Register is maintained in which a serial reference number is allocated to each seed lot distributed.

Notes on the primary observation plots are entered on Observation Plot Cards. These cards of size 8 in. × 5 in. are also printed by Moores Modern Methods Ltd to our design and are kept while in use in field binders. Upon completion the cards are filed behind the relevant Species Record Card. Notes on the larger observation plots and of experiments are kept in log books in the routine described by GISBORNE (1958).

PASTURE GRASSES

Perennial grasses are mainly of interest in Northern Nigeria as constituents of leys and permanent pastures. Other species surpass them in the production of fodder. A perennial grass for use in a ley should fulfil the following requirements:

(*1*) The species should be easy to establish which implies the production of viable seed
(*2*) It should yield well into the dry season and start growth promptly on the onset of the rains
(*3*) It should be productive and relatively palatable and nutritious
(*4*) It should survive the dry season
(5) It should be fairly easy to eradicate.

The species which best fulfils these requirements is *Andropogon gayanus*, known in Northern Nigeria as *Gamba*. This species is indigenous throughout Northern Nigeria except in northern Sokoto and northeast Bornu Provinces, and merges at the southern boundary of Northern Nigeria with the closely related species *A. tectorum*. Yield data on this and on other perennial grass species have been presented by RAINS (1957, 1959) and his results are summarized in *Table 2*. There is a considerable amount of morphological

Table 2. Yield of dry matter of several perennial grass species at Samaru in pounds per acre per three-year period (After RAINS, 1957, 1959)

Species	1953–55	1954–56
Andropogon gayanus	13 646	—
Hyparrhenia rufa	—	11 415
Chloris gayana	10 179	9 643
Pennisetum polystachyon	10 124	—
Setaria sphacelata	—	8 590
Cenchrus ciliaris	6 183	8 215
S.E.	1 048	1 460

variation within the species *A. gayanus* which is to a certain extent recognized by its division into four varieites; *gayanus*, *squamulatus* (Hochst.) Stapf, *bisquamulatus* (Hochst.) Hack. and *tridentatus* (Hochst.) Hack. (personal communication from D. C. Clayton). In addition, cytological variation has been reported by V. Chapman of the Plant Breeding Institute, Cambridge (personal communication from Dr Bell) and by D. N. Singh of Queen Mary College, London (personal communication) but so far little correlation has been made between this cytological variation and the varietal classification. This subject is still under active investigation as part of a breeding programme on this species. It is anticipated that selection within this one species will produce two or three improved varieties which between them will cover the wide climatic range which exists in Northern Nigeria.

For permanent pastures where ease of establishment and eradication are not of such importance, other species including those which are established from vegetative material can be considered. For this purpose, in addition to the ley grasses, *Pennisetum purpureum*, *Panicum maximum* (both of which are indigenous in the Southern Guinea zone), *Digitaria* sp. (Rietondale) obtained from South Africa and *Brachiaria brizantha* are suitable for use throughout the Guinea zones.

Twelve introductions have been made of *Chloris gayana* which have displayed a wide range of variation in habit. A limited amount of phenotypic selection on habit has been carried out but no variety has proved to be of great value in Northern Nigeria. It will hardly survive the dry season in the Sudan zone and is always outyielded by *Andropogon gayanus*. Twelve introductions have also been made of *Cenchrus ciliaris*. Pastures of this species have been established vegetatively at Ibadan in Western Nigeria but observation work in Northern Nigeria suggests that this species is of too low productivity to be of value except in the Sudan zone where its ability to exist under low rainfall conditions may be of use. Giant star grass, *Cynodon plectostachyus*, is also used in the Western Region of Nigeria but its area of usefulness has been found to be restricted to the Southern Guinea zone.

An indigenous species, *Anthephora nigritana*, has produced leafy herbage and shown good dry season survival even in the Sudan zone, and investigations into the use of this species are continuing. Poor seed production appears to be a limitation to its wider use for pasture. Five other indigenous grasses which in the past have been considered as possible pasture species have been discarded; *Hyparrhenia rufa* due to the low quality of its herbage, *Pennisetum polystachyon* due to its habit of ceasing growth early in the dry season, *Setaria sphacelata* due to poor herbage production, and *Melinis minutiflora* and *Paspalum scrobiculatum* due to poor persistency and low productivity.

Pennisetum clandestinum, Kikuyu grass, is of possible value for permanent pastures on the Jos Plateau in areas of high fertility. In Northern Nigeria some altitude appears to be a necessity for the survival of this species.

PASTURE LEGUMES

A large number of species, introduced and locally collected, have been observed in the search for a suitable legume to combine with a perennial

grass in a pasture sward. This aspect of the work has been complicated by the question of the inoculation of legumes with suitable strains of *Rhizobium*. In 1956 all legumes grown in primary observation plots at Shika were inoculated with a commercial cowpea type culture (except with *Lespedeza*, *Medicago* and *Trifolium* spp. where the appropriate *Rhizobium* strain was used). No beneficial effect due to this inoculation was noted. Recent publications have suggested that broadly speaking in the tropics there is little advantage in using a general cowpea cross-inoculation group inoculum as '. . . it is likely that a legume species will nodulate successfully anywhere it or its relations are endemic . . .' (NORRIS, 1958). Specific strains of *Rhizobium* are only available to a very limited extent in Northern Nigeria and it has been impossible with the large number of legume species to be tested to obtain a specific strain of *Rhizobium* in each case. Generally legumes sown in observation plots have not been inoculated.

In the Sudan zone no suitable legume species has been observed capable of surviving the dry season. *Stylosanthes gracilis* is the only species which shows any promise in this character. The possibility of using self-seeding annual legumes in a perennial pasture has been considered and *Calopogonium mucunoides* would be the most suitable species to use in this way. Other annual legumes such as *Stylosanthes sundaica* and *Alysicarpus glumaceus* are of too low productivity to be of use.

In the Guinea zones there are four legumes of suitable habit which are of use as pasture legumes: *Stylosanthes gracilis*, *Centrosema pubescens*, *Desmodium scorpiurus* and *Atylosia scarabaeoides*. These four species are being observed in large observation plots in mixed swards with *Andropogon gayanus*.

FODDER CROPS

In the Northern Guinea zone it does not appear likely that any pasture species will be found which can provide grazing from mid January to mid April, that is during the later half of the dry season. Farther north in the Sudan zone this period is correspondingly longer and during this period animal feeding must depend upon conserved fodders. Dried groundnut haulm, a common by-product from the farms, is used for this purpose but it does not meet the total requirements. There is thus a place in the farming system for crops grown especially for hay or silage. The final evaluation of such material by digestibility trials is outside the scope of this article but is being pursued by Dr T. B. MILLER.

Three legume species are of value for conservation; *Vigna sinensis* (cowpea), *Glycine max* (soya bean) and *Stizolobium deeringianum* (mucuna or velvet bean). Variation exists within these species and work is continuing on the selection of the most suitable varieties. Although these species have made relatively high quality hay, they have not yet been made successfully into silage. It is likely that a mixture of a cereal and one of these legumes will prove to be the most suitable silage crop. Cereals which have a suitable habit for this purpose are *Sorghum caudatum* and *Pennisetum typhoideum* (' *maiwa* '). Both these cereals combine well with *Stizolobium deeringianum* to produce a mass of leafy herbage. At the present stage of the development of this country, however, it is unlikely that the farmer can be persuaded to cut these species for silage as they are his principal grain crops. Sweet sorghum

which has been commented upon favourably in the literature has not yet been observed. Sunflower which in the past has been used on Government farms for the production of silage has recently been shown to be of relatively low feeding value (MILLER, 1961).

The annual grasses *Pennisetum pedicellatum* and *P. subangustum*, known locally by the collective name *Kyasuwa*, are the most promising of the indigenous grasses for conservation. Yield data on these species have been presented (FOSTER, 1957). A wide range in leafiness and earliness has been observed and a selection programme to produce improved varieties of these two species is in progress.

BROWSE PLANTS

Browse plants are of considerable importance as stock food during the later half of the dry season in the Sudan zone when the grass cover has been removed by fire or grazing, which occurs practically every year. The local herdsmen are aware of the value of these shrubs and trees which occur fairly frequently throughout the zone.

The leaves of several species are eaten to a certain extent including *Guiera senegalensis* (' *sabara* ') which is widespread throughout the zone, in many areas being the dominant shrub, *Boscia senegalensis* (' *dilo* ') which is found on the heavier soils, *Combretum micranthum* (' *geza* '), *Piliostigma reticulatum* (' *kalgo* ') and *Dicrostachys glomerata* (' *dundu* '). Sometimes the branches of the larger trees such as *Prosopis africana* (' *kirya* ') and *Acacia albida* (' *gawo* ') are lopped to allow cattle to graze on the leaves.

The fruits of trees and shrubs form an important item in the dry season diet of stock in the Sudan zone. The pods of *Piliostigma reticulatum*, *Acacia albida*, *A. nilotica* and *Parkia clappertoniana*, and the fruits of *Zizyphus mauritiana* and *Z. spina-christi* are the most important but the pods of most leguminous trees and shrubs are eaten to some extent. Their digestibility has not been determined.

Few introductions of browse plants from other countries have so far been made. Pigeon pea, *Cajanus cajan*, is the only species which has so far shown promise but the artificial establishment of this species or indeed of any of the indigenous species, in rangeland presents considerable difficulties.

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APPENDIX I

A list of the better known grass and legume species and the more promising indigenous species which have been observed for forage value in Northern Nigeria includes the following:

Alysicarpus glumaceus
Anadelphia arrecta
Andropogon gayanus
A. tectorum
Anthephora nigritana
Atylosia scarabaeoides
Beckeropsis uniseta
Bothriochloa intermedia
Brachiaria brizantha
B. mutica
B. ruziziensis
Cajanus cajan
Calopogonium mucunoides
Cenchrus ciliaris
Centrosema plumieri
C. pubescens
Chasmopodium caudatum
Chloris gayana
Clitoria ternatea
Crotalaria intermedia
C. mucronata
C. paulina
C. retusa
C. spectabilis
C. usaramoensis
Cymbopogon giganteus
Cynodon dactylon
C. plectostachyus
Desmodium gyroides
D. scorpiurus
D. uncinatum
Dichanthium caricosum
Digitaria decumbens
D. smutsii
D. sp. (Rietondale)
D. sp. (Thabazimbi)
D. sp. (Umfolosi)
Dolichos lablab
Ehrharta calycina
Eragrostis alba
E. curvula
E. superba
E. tef
Glycine javanica
G. max
Heteropogon contortus
Hyparrhenia cyanescens
H. rufa
H. sp. near *hirta*
Indigofera spicata
I. suffruticosa
Ischaemum indicum
Ixophorus unisetus
Jardinea congoensis
Lespedeza cuneata
L. stipulacea
L. striata
Leucaena glauca
Medicago sativa
M. truncatula
Melinis minutiflora
Oryzopsis miliacea
Panicum antidotale
P. coloratum
P. makarikari
P. maximum
P. maximum var. *trichoglume*
Paspalum conjugatum
P. dilatatum
P. notatum
P. plicatulum
P. scrobiculatum
P. virgatum
Pennisetum clandestinum
P. pedicellatum
P. polystachyon
P. purpureum
P. subangustum

P. typhoideum (' *maiwa* ')
Phalaris tuberosa
Phaseolus lathyroides
Pueraria phaseoloides
Rottboellia exaltata
Setaria chevalieri
S. sphacelata
Sorghum almum
S. caudatum
Stizolobium deeringianum
Stylosanthes gracilis
S. sundaica
Tephrosia candida
Teramnus labialis
T. uncinatus
Themeda triandra
Trachypogon plumosus
Trifolium alexandrinum
T. fragiferum
T. incarnatum
T. repens
T. rueppellianum
T. subterraneum
Tripsacum laxum
Urochloa pullulans
Vigna sinensis
Zea mays

Observations on a Cross Breeding Experiment with Cattle in Nigeria

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A combined meeting of the Agricultural and Veterinary Departments of Nigeria was held in 1950 to consider the problem of milk supply to urban areas. It was recognized at this meeting that the local cattle breeds were not suitable for economic milk production, and that selective breeding of these cattle for milk production was too slow a method to satisfy the rapidly growing demand of the densely populated areas. A programme of cross breeding the local cows with exotic male stock from a dairy breed was therefore drawn up. The exotic breed chosen was Friesian, and one of the centres selected in the programme was the Federal Veterinary Department's farm at Vom where the local White Fulani females were crossed with Friesian bulls using semen imported from Britain by air. The artificial insemination techniques employed and the results obtained have already been reported (Armour and Sainsbury, 1956).

The purpose of this paper is to record the performance of the Friesian–White Fulani cross and their adaptability to the local environment.

MATERIALS AND METHODS

Vom is situated on a plateau over 4 000 ft above sea-level with an approximate annual rainfall of 55 in. The highest mean monthly maximum temperature is 88°F and the lowest mean monthly minimum temperature is 57°F. The mean relative humidity at 06.00 hours varies between 33 and 97 per cent and at 12.00 hours between 14 and 74 per cent.

Male calves were castrated and subsequently slaughtered before they reached 2 years old. No data were recorded on the male progeny. The female Friesian–Zebu calves, hereafter called cross-Friesians, were reared in exactly the same way as the pure Zebu calves on the farm, i.e. artificially fed using whole milk until weaning at 6 months. Hay and concentrates were fed from 3 weeks. From weaning until calving a daily supplement of 1 lb of groundnut cake was fed during the six months of the dry season, i.e. October to April. Milk cows were given a production ration (55 per cent Guinea corn, 22·5 per cent maize, 22·5 per cent groundnut cake) at a rate of 4 lb per gallon of milk produced. Silage at a rate of 10 lb per head was fed in the dry season. A mineral supplement was fed throughout the year. Weekly dipping using a benzene hexachloride preparation was carried out.

RESULTS

General data

Sixty three cross-Friesian calves were born as the result of the insemination programme (31 male, 32 female). Unlike their Zebu dams they were

humpless. Colour variations were wide, though several of the crosses showed typical Friesian markings (*Figure 1*). The pendulous sheath and dewlap typical of the Zebu (*Figure 2*) were not prominent in the cross-Friesians.

Figure 1. Cross-Friesian heifer

Figure 2. White Fulani heifer

The average birth weight of the male cross-Friesian calves was 58·6 lb compared with 51·8 lb for male White Fulani calves born over the same period. Female cross-Friesian calves averaged 58·4 lb compared with 49·5 lb for female White Fulani calves at birth.

Milk production

All available data on the milk production of the cross-Friesians, their Zebu dams and Zebu half-sibs are presented in *Table 1*. Complete records are available for the first two lactations of 25 cross-Friesians and their Zebu dams. Only eleven first lactation and six second lactation records of the half-sibs are available as yet. *Table 1* is divided into two sections to give direct comparison between the cross-Friesians and their dams and between

the cross-Friesians and their half-sibs. In this it will be seen that the first lactation milk yields of the cross-Friesians show an increase of 138 per cent over those of their Zebu dams and an even greater increase of 168 per cent when the second lactation milk yields are compared. An increase of slightly over 100 per cent at the first lactation and slightly under 100 per cent at the second lactation can be seen when the respective lactations of the cross-Friesians and their Zebu half-sibs are compared.

Table 1. Lactation records of cross-Friesians, Zebu dams and Zebu half-sibs

Breeding	*No. of animals*	*Mean age at first calving months*	*Mean calving interval 1st to 2nd lactation, days*	*Mean yield first lactation lb*	*Mean yield second lactation lb*
Zebu dams	25	50	362	1 620	1 400
Cross Friesian–Zebu	25	32	371	3 850	3 750
Zebu half-sibs	11	47	415	1 890	1 920*
Cross Friesian–Zebu	11	32	373	3 730	3 710

Breeding	*Range of first lactation lb*	*Range of second lactation lb*	*Mean length of first lactation days*	*Mean percentage butterfat*
Zebu dams	*Nil* —4 330	*Nil* —3 070	241	*N.A.*
Cross Friesian–Zebu	2 310 —5 460	2 150 —6 590	299	5·3
Zebu half-sibs	*Nil* —3 120	720 —3 230	258	6·0
Cross Friesian–Zebu	2 310 —5 460	2 460 —6 000	300	5·3

* 6 second lactations only.

Heat tolerance

A comparative heat tolerance test using the Iberia formula (Rhoad, 1944) with the cross-Friesians and White Fulani herds showed the coefficient of heat tolerance of the former to be 85 compared to 89 for the indigenous breed. The mean maximum temperature recorded over the three days of the test was 89°F and the mean minimum was 65°F.

Health

There were only two deaths among the cross-Friesians, both due to heartwater. Two other animals had to be destroyed, one with a broken leg and the other following a positive Johne's test. Local vaccines were administered without ill effect. No parturition difficulties were encountered.

DISCUSSION

The heavier birth weights of the cross-Friesian calves are in agreement with the results recorded by Rhoad, Phillips and Dawson (1945), who

found when working with beef breeds that in wide crosses, the sire affects the birth weight of the progeny. The body weight of mature cross-Friesians at Vom was 990 lb compared with 800 lb for mature White Fulani females at Vom.

The average age at first calving of the cross-Friesians was 33 months, which compares favourably with results obtained elsewhere with Friesian–Zebu crosses. LECKY (1949) quotes 42·3 months as the average age at first calving, while HUTSON (1953) states that 24 months is the minimum age at which cross-Friesian heifers were bred in Trinidad. According to STONAKER (1953) the age at first calving is a highly heritable factor and LECKY (1951) confirmed this in Nigerian White Fulani cattle but he pointed out also that the late age at first calving of some crossbred cattle in the tropics is not genetic in origin but is an indication of their lack of adaptability to the climate. If this is so, the cross-Friesians in Vom appear to be adaptable to the climate there, as the mean age of 33 months at first calving compares favourably with 27–30 months for Friesians in Great Britain.

The intervals between first and second calvings of the cross-Friesians at Vom did not differ greatly from those of their Zebu dams but were shorter by 42 days than their Zebu half-sibs. The latter increase in the calving interval of the Zebu-sibs, compared with that of their Zebu dams, is probably associated with the longer lactation and greater milk yields of the Zebu half-sibs. The differences in age at first calving mean that a cross-Friesian will have begun her second lactation before her Zebu half-sibs have calved for the first time.

MAULE (1953) has pointed out that Friesian–Zebu crosses have proved superior to all other crosses between European breeds and Zebu cattle in terms of improvement in milk yield. He tabulates results from workers in various parts of the world showing the percentage improvement in milk yield of cross-Friesians over their Zebu dams; for example, MACGUCKIN (1937) working in India with Friesian–Zebu crosses showed an increase in milk yield of 81 per cent by the cross-Friesians over their dams. Similarly, HUTSON (1953) in Trinidad reported an overall increase in herd average milk yield from 252 gallons to 635 gallons between 1948 and 1952 using half and three-quarter bred Friesian–Zebu crosses. The Vom data of 138 per cent and 168 per cent increase in milk yield at first and second lactation therefore compare favourably with results in other areas of the world.

The butterfat percentages of the cross-Friesians are, considering the relative milk yields, intermediate between those of their parents, which agrees with MAULE (1953) who stated that butterfat percentages of cross-breeds tend to be intermediate between those of the parents.

CONCLUSIONS

Taking into consideration the health, heat tolerance and increased milk yield of the cross-Friesians at Vom, the introduction of Friesian blood into Nigerian Zebu cattle in an effort to produce an economic milk-yielding animal, suitable for urban dairies, seems worthy of further consideration. Whether the first cross or half-breed is the most desirable choice or whether a greater amount of Friesian or Zebu blood would be more suitable remains to be studied.

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Responses of Cocoa to Copper Sprays in Ghana

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Black Pod of cocoa, caused by *Phytophthora palmivora* Butl., has been reported as causing as much as 70 to 80 per cent loss of crop in the wetter areas of Ghana (Broatch, 1956) and overall probably causes not less than 10 per cent crop loss, or the equivalent of 20–25 000 tons per annum (Broatch, 1955).

The standard control measure recommended to the Ghana cocoa farmer was, and still is, frequent harvesting of ripe pods and the removal and burial of diseased pods. Many attempts at fungicidal control gave little or no apparent response, certainly nothing approaching that obtained from carbide–Bordeaux spraying in Nigeria (Thorold, 1955).

In order to decide finally whether or not spraying would provide an economic control of Black Pod, an extensive series of trials was laid down in 1954 in cooperation with Plant Protection Ltd. The original intention was to compare a copper and a sulphur fungicide, but the trial eventually became a comparison of two methods of applying the copper fungicide, Perenox. The treatments were:

(*a*) Perenox applied overall with a motorized knapsack mistblower, at 5 per cent, in 10 gallons of water per acre; 3-weekly intervals in 1954–55, later increased to 2-weekly intervals. This treatment is referred to as LV.

(*b*) Perenox applied at an equivalent concentration to pods only by means of a pressure-retaining hand-operated knapsack sprayer, only those pods within reach of a 6 ft lance being sprayed. The gallonage obviously varied with the number of pods to be sprayed; frequency of spraying was as in (*a*). This treatment is referred to as HV.

(*c*) Check, no spraying, referred to as C.

A total of 28 sites was originally selected, 14 each in Eastern Region and Ashanti. The main criterion of site selection was a heavy and probably limiting incidence of Black Pod; uniformity of cocoa, capsid attack, etc., were secondary considerations. Most of the sites, or Units, contained one replicate of each treatment, and Units were widely spread within the regions in an attempt to offset the absence of random allocations within Units. Spraying was done by teams under the control of the district officers in whose areas the Units were sited.

For a variety of reasons some Units were dropped at the end of the 1954–55 season, but 18 were maintained until August 1956, when the trial was stopped as it was at that time considered that the results were inconclusive. However, closer examination of the data obtained suggests that results of some interest were overlooked. Data from 15 Units have been analysed, 7 in Eastern Region, located at Nsutam, Akwasiho, Tetteh,

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Bomaa, Mpraeso Scarp Upper, Mpraeso Scarp Lower, Framase and Ankase-Amanfrom; and 8 in Ashanti, 5 at Apimso, 2 at Juaso and one at Asamang. Data are available for two other Units, one each in Eastern Region and Ashanti, in which HV and C only were included, but these Units have been omitted from the main analyses.

The trial has been analysed as for an orthodox randomized block layout, since each treatment was present and allocated within Units. A very undesirable feature of the layout was the variable size of each treatment area within a Unit. This is, in part, a consequence of the different plot sizes necessary for adequate work with motorized and hand equipment, particularly when individual pod spraying by hand is involved, but these considerations affected randomization and particularly the placing of the C plots, which were usually the smallest in size and relegated to the least convenient piece of the Unit. The disparate sizes of the treatment areas within Units has necessitated transformation of the yield results; the transformation used has been standardization to the least area involved, which in both Eastern Region and Ashanti has been a C plot. This transformation is preferable to calculating yields per acre, since this would frequently have required extrapolation over an assumed population of unknown characteristics, whereas although there is no guarantee that the population of any treatment area is uniform, reduction over a sampled population probably contains less error.

Separate analyses have been made for Eastern Region and Ashanti, and in the following categories: total Black Pod incidence; Diseased Ripe Pods (DRP); Diseased Unripe Pods (DUP). All are expressed as

Table 1. Black Pod incidence as percentage of total pods

	Eastern Region			*Ashanti*		
	Total	*DRP*	*DUP*	*Total*	*DRP*	*DUP*
1954–55						
LV	31·5**	17·3**	13·3**	33·9	18·6*	15·4
HV	29·7**	16·3**	13·1**	24·0**	14·1**	9·5**
C	41·7	23·3	17·7	40·9	22·4	18·0
C.V.%	8·9	6·9	11·6	11·8	10·7	15·7
1955–56						
LV	29·5*	10·1**	11·4**	27·3	16·0*	10·5*
HV	31·7	10·7**	14·1	19·0**	13·9**	4·9**
C	35·6	13·7	19·2	34·1	20·4	13·2
C.V.%	14·3	7·7	18·1	17·6	12·4	26·7

Ashanti—HV and LV only

	Total	*DRP*	*DUP*
1954–55			
HV	24·0**	14·1*	9·5**
LV	33·9	18·6	15·4
1955–56			
HV	19·0**	13·9*	4·9*
LV	27·3	16·0	10·5

Table 2. Diseased unripe pods as percentage of total diseased pods

		LV	*HV*	*C*
Eastern Region	1954–55	40·8	43·0	45·1
	1955–56	50·1	54·5	51·9
Ashanti	1954–55	46·5	41·2	43·6
	1955–56	49·3	27·9	41·9

No significant differences

percentages and presented re-transformed after analysis following angular transformation. Yield has been expressed as total pods and as total usable pods, presented re-transformed as a percentage of C after analysis by angular transformation, subsequent to the standardization mentioned above.

Consideration of the disease incidence analyses in *Tables 1* and *2* shows that overall the spray treatments have achieved some control, although in few cases has this been much more than marginal. This relatively poor degree of control of infection has been typical of numerous experiments in Ghana and contrasts with those obtained elsewhere.

The performances of the two types of spray differ markedly between the regions. In Eastern Region LV was slightly worse than HV in 1954–55, but slightly better in 1955–56. In Ashanti, on the other hand, HV is consistently and markedly better than LV in both years. On only three occasions has LV proved significant in Ashanti, and then at the 5 per cent level only. The superiority of HV in Ashanti is evident in both years and has produced somewhat more than marginal control, the overall incidence being reduced from 41 per cent to 24 per cent in 1954–55 and from 34 per cent to 19 per cent in 1955–56. Why this difference between the two regions should exist is not clear. When this trial was first discussed as a Departmental report in 1957 the writer suggested that strain differences in the pathogen might be responsible, and it is thus of interest that WHARTON (1959) has recently shown that a Mampong (Ashanti) isolate of *P. palmivora* is culturally different from other Ghana strains. The existence of ' cocoa ' and ' rubber ' strains (WHARTON, 1958, TURNER, 1960), which appear to have separate areas of distribution, may also explain the differences in level of control achieved in Ghana compared with, e.g., Nigeria if these strains should differ in their epidemiology and/or susceptibility.

The incidence of diseased unripe pods (*Table 2*) is worthy of note. With the exception of the 28 per cent recorded for HV in Ashanti 1955–56, the incidence is between 41 per cent and 55 per cent, possibly giving some support to the view that a major source of loss from Black Pod is among cherelles and immature pods. The distinction between these categories is arbitrary, cherelles being ' pods ' younger than 13 weeks, pods those older than 13 weeks. Cherelles were not recorded in this trial and since no records of individual pod development were made, a considerable proportion of diseased unripe pods could probably have been termed cherelles. WHARTON (1959) in Ghana and THROWER (1960) in New Guinea have given data showing the degree of infection of cherelles, the latter estimating that Black Pod was directly responsible for 25 per cent of the total wilted cherelles. He also showed that cherelles below 4 cm in length were not affected, and that *P. palmivora* was proportionately more abundant

on the larger cherelles, i.e. those near or at the 13-week age distinction between cherelle and immature pod. It would thus appear that a fair proportion of cherelles was lost to *P. palmivora* in the Ghana trial, and it would seem desirable to record, in any future trials, disease occurrence on cherelles as well.

Yield analyses for the trial are set out in *Table 3*. In *Table 4* plot yields for LV and HV for each Unit are expressed as percentages of C.

Table 3. Pod yields as percentage of control = 100

	Eastern Region		*Ashanti*	
	Total pods	*Total usable*	*Total pods*	*Total usable*
1954–55				
LV	136**	153**	121	127
HV	111	126	81	92
C	100	100	100	100
C.V.%	21·6	23·7	51·8	52·3
1955–56				
LV	134	156*	114	121
HV	119	138	84	99
C	100	100	100	100
C.V.%	23·8	35·8	30·4	35·0

Table 4. Individual plot yields of usable pods for each unit expressed as percentage of control = 100

Unit	1954–55 *LV*	1954–55 *HV*	1955–56 *LV*	1955–56 *HV*
Eastern Region				
Nsutam	416	430	1 412	1 447
Akwasiho	167	136	168	120
Tetteh	107	72	195	117
Bomaa	129	119	69	86
Mpraeso	420	321	807	629
Framase	107	135	108	101
Ankase	176	108	133	103
Mpraeso†	—	204	—	221
Ashanti				
Apimso 1	183	155	156	121
Apimso 2	128	115	125	132
Apimso 3	160	67	137	53
Apimso 4	155	136	208	161
Apimso 5	70	114	53	106
Asamang	139	39	140	71
Juaso 1	88	36	72	79
Juaso 2	204	406	325	284
Asamang	—	112	—	121

† Not included in analyses because LV treatment omitted.

The general level of statistical significance is much less than for the disease analyses. Nevertheless, significant increases have been demonstrated in both years from LV in Eastern Region, and in Ashanti there is a strong trend in favour of LV and to a lesser extent, in Eastern Region, in favour of HV.

Reference to the disease analyses shows that only a partial control of Black

Pod has been achieved, yet there are definite yield increases. For instance, in 1955–56 Eastern Region, disease was reduced by 6 per cent and 4 per cent in LV and HV respectively, whereas yield increases averaged 54 per cent and 19 per cent in total pods and 56 per cent and 38 per cent in usable pods. It could be suggested that control of cherelle loss is responsible for this effect. There is unfortunately no evidence from this trial to support this view, and moreover, from the data provided by THROWER (1960) and that presented here on the level of control achieved in pods and apparent absence of any control in diseased unripe pods, it is doubtful whether anything more than a minor proportion of this unexpected increase can be accounted for by control of cherelle infection.

A probable explanation is that a tonic response to copper has occurred. There is now evidence that foliar sprays of copper can produce responses in yield and in general condition of trees (see e.g. RAYNER, 1951; TOLLENAAR, 1959—this author summarizes the literature with reference to cocoa). The results now obtained in Ghana suggest that further work on foliar applications of copper will prove rewarding.

Another important feature is the yield disparity between LV and HV treatments. In Eastern Region there is very little difference in the control of Black Pod achieved, while in Ashanti HV was always better than LV. Yet, in Eastern Region the increase from LV is about twice that from HV, and in Ashanti HV seems to have had a marked adverse effect on yield.

Reference to *Table 4* shows that, for reasons unknown, three Units in Ashanti had remarkably bad HV plots which have obviously affected the regional mean. Nevertheless, there is a marked advantage in favour of LV; in only 11 out of 28 comparisons in the two regions has HV approached within 10 per cent or surpassed LV in yield.

Part of this disparity between fungus control and subsequent overall yields may be explained by a difference in control of disease in the canopy, a great many pods being inaccessible to the 6 ft lance on the hand sprayer. It has also been shown (HOLLIDAY, 1954; RENAUD, 1957; TOLLENAAR, 1959) that high volume application has a depressing effect on pod production, apparently due in part to the use of copper before and during the main flowering period, and also because of the large droplet size of the spray and the volume of liquid applied. The data from this Ghana trial certainly seem to support the conclusion that high volume spraying is not beneficial, and indicate that future work should be restricted to low volume sprays.

One would also, of course, expect a differential response to copper when one treatment applies a general trunk and canopy spray, the other mainly to the trunk. This difference in yield response, combined with the very small differences in disease control achieved—and in Ashanti HV was actually better in this respect than LV—is perhaps the strongest argument in favour of a tonic response.

The large variability between Units is also illustrated by *Table 4*, and reflected in the high coefficients of variation in the yield analyses. This is to be expected when, as stated earlier, little or no attention was paid to factors other than Black Pod incidence, and no pre-recording was done. The desiderata for experimental layouts in Ghana cocoa have been discussed by HOBLYN (1956). While in such essentially *ad hoc* work as disease

control experiments it may not always be possible to calibrate plots as Hoblyn has suggested, it is eminently desirable that at least two years pre-recording be done, and that plot sizes be standardized to avoid unnecessary transformations. Since it seems that there is little point in pursuing further investigations into high volume spraying, uniform plot size should not be difficult to achieve. Also, it is necessary to apply standard capsid treatments as an aid to uniformity.

It would also be desirable to increase the scope of recording, if only on a sample basis, to include at least cherelle losses and other causes of loss. These may exert a considerable influence on ultimate yields for analysis. For instance, in 1955–56 both treatments at Nsutam (E.R.) gave increases in usable pods of over 14 times. The actual Unit records show that for *total pods* the increases were 1·7 and 1·6 times for LV and HV respectively. Obviously, some heavy but unrecorded pod loss occurred in the unsprayed plot at Nsutam.

On the other hand the layout adopted appears to be adequate for fungicide trials if one merely wishes to record levels of infection and control achieved. The coefficients of variation in the disease analyses (*Table 1*) are all low, only four being above 15 per cent. The between-Unit variation was usually significant in Eastern Region, but not in Ashanti. This regional difference in between-Unit variation is not, apparently, influenced by the inclusion of scarp and lowland sites within Eastern Region, since removal of two scarp sites does not affect between-Unit variation in that region. Nevertheless, the use of large-scale units spread over a big tract of country seems to offer a surprisingly sensitive tool for Black Pod control experiments.

SUMMARY

Experiments on control of Black Pod (*Phytophthora palmivora* Butl.) in Ghana are described. Both low volume and high volume Perenox sprays reduced Black Pod incidence, although this was frequently marginal.

Both treatments have resulted in an overall increase in both total pods produced and usable pods in Eastern Region, the increases being highly significant for low volume spraying. In Ashanti the same trend is apparent but is obscured by large Unit variation.

Increases of yield were considerably more than expected from the level of control achieved. It is suggested that this is due, in part at least, to a tonic response to copper. There was a consistent trend in favour of low volume spraying, due possibly in part to better control of infection in canopy pods, in part to adverse effects of high volume spraying and also to a differential response to copper.

Some suggestions are made for improving the efficiency of the large-scale layout used, which even in the form described appears sensitive enough to show small differences in disease incidence.

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A Note on the Pruning of Amazon Cocoa in Ghana

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The pruning of tree crops, especially those of temperate and sub-tropical regions, is a common practice aimed at shaping the canopy to give maximum production and where possible, to facilitate such operations as harvesting and spraying. Because of its characteristics—dimorphic branching, growth habit and flowering—cocoa does not lend itself to the same pruning treatments as other tree crops grown for their fruit (van der Knaap, 1955). At spacings up to 12 ft × 12 ft cocoa is ' self-pruning ' as branches developed on the lower trunk are shed as the canopy closes. The pruning of cocoa is therefore confined to limiting the vertical growth from the first or second jorquette and thereby forcing the tree to expand laterally.

In 1952 in all three spacings of the Amazon Spacing Trial at the West African Cocoa Research Institute (Benstead and Wickens, 1954) the plots were split to compare the yields of unpruned trees with others in which growth was restricted to the first jorquette.

Routine protection against capsid damage was achieved by spraying with gamma benzene hexachloride (BHC) at regular intervals starting from 1956, the eighth year after planting, although some protection had been given with dichlorodiphenyl trichloroethane (DDT) from 1954 onwards.

Shade was reduced in 1958 by poisoning selected (forest) trees with one part of a proprietary mixture of 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) and 2,4-dichlorophenoxyacetic acid (2,4-D) mixed with ten parts of a 1 : 1 mixture of sump oil and kerosine. At the same time, annual routine application of a fertilizer mixture containing nitrogen, phosphorus, potassium and magnesium commenced.

The effect of pruning on yield may be assessed from the data in *Table 1*. For the first six years the annual yield of the pruned plots was constantly slightly higher than that of the unpruned plots. For the last two years, the unpruned plots gave a significantly higher yield than the pruned plots, while the yield from the start is approximately 13 per cent higher (*Figures 1* and *2*).

The condition of the pruned cocoa in the field is not satisfactory. The canopy is incomplete and consequently weed growth is excessive. The weight of pods borne on the branches often causes the branches to break. The individual canopies are very uneven, trees having jorquetted at varying heights.

Figure 1. Unpruned cocoa. Note complete canopy and absence of weed growth

Figure 2. Pruned cocoa. Note low branching habit and irregular canopy. (The poor growth in the foreground is due to impeded drainage and is not included in the experimental area.)

Table 1. Yield expressed in pounds dry cocoa per acre of pruned and unpruned upper Amazon cocoa, Tafo, Ghana for the years 1951–2 to 1959–60

Year after planting	*3rd*	*4th*	*5th*	*6th*	*7th*
Season	1951–2	1952–3	1953–4	1954–5	1955–6
Pruned	7·6	72·3	206·0	261·0	214·7
Unpruned	5·1	62·3	181·0	245·4	208·1
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

Year after planting	*8th*	*9th*	*10th*	*11th*	*Total*
Season	1956–7	1957–8	1958–9	1959–60	
Pruned	294·5	645·1	1 090·7	1 084·5	3 876·4
Unpruned	287·7	650·2	1 288·3	1 461·9	4 390·0
Significance	*N.S.*	*N.S.*	*	†	

N. S.—Not significant; *—Significant at $P = 0{\cdot}05$ level; †—Significant at $P = 0{\cdot}01$ level.

CONCLUSIONS

From the results it is obvious that the pruning of cocoa by limiting its growth to the first jorquette ultimately depresses the yield, even if the yield in the early years is higher than for unpruned cocoa. The incomplete canopy is a highly undesirable feature because of the invasion of strong weed growth. Because of the relatively low branching habit, access to the unpruned plots by spraying teams and harvesting gangs is not as easy as was first anticipated (TAYLOR and NICOL, 1954).

DISCUSSION

Observations at present being made on the distribution of pods on a tree indicate that with Amazon cocoa the major part of the crop is borne in the canopy while with Amelonado the larger proportion is carried on the trunk (SMITH, 1960). Amazon cocoa has a lower trunk/branch ratio than Amelonado unless Amelonado is planted at a wide spacing. As the canopy of pruned cocoa was far from complete at all the spacings, and the length of trunk available for pod production was very much less than in the unpruned cocoa, it is not surprising that the pruned cocoa gave a lower yield.

The higher yield from the pruned cocoa for the first eight years may be attributed to the fact that vegetative growth was limited during this period while the vegetative growth of the unpruned cocoa proceeded at the expense of pod production. By the beginning of the ninth year, maximum height on the unpruned cocoa had been obtained, and by virtue of its greater canopy and larger trunk, it produced more pods.

In the season 1958–59, following the first application of fertilizer, the increase in yield was greater on the unpruned cocoa than on the pruned. This is considered to be due partly to the strong weed growth which existed on the pruned cocoa and partly to the decreased bearing area.

Current ideas on pruning must be governed by the growth habit of cocoa. Bearing in mind the stimulating effect of pruning on all perennial fruit crops, the advocacy of restricting cocoa by pruning its growth is a doubtful

policy. It is suggested that there is scope for investigation of pruning of the canopy to encourage strong pod-bearing branches by reducing the number of branches in the canopy. A pruning régime adopted on these lines would necessarily have to be carried out with care to prevent too great a destruction of the canopy. A careful examination of a cocoa canopy is not necessary to realize that there are many sub-grade branches which do not appear to be contributing much, if anything, to the crop.

SUMMARY

The results of a pruning trial carried out at Tafo, Ghana, on Amazon cocoa show that pruning, by restricting growth to the first jorquette, has a limiting effect on the yield. It is suggested that this method of pruning may not be the most advantageous, while consideration may well be given to pruning methods adopted for other perennial fruit crops.

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Platynota rostrana *(Walker)*: *A Peel-feeding Pest of Bananas*

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The fruit of the banana plant is attacked by numerous insects, among them several species of caterpillars which feed on the peel. These include the scab moth *Nacoleia octasema* Meyr. reported by O'Connor (1949), and *Heliothis armigera* Hb. found by Smith and Weddell (1949) in test plots of an experiment designed to study chemical control of red rust thrips. *Amorbia catenana* (Wlsm.), identified from the pulp of a ripe finger, was considered by de Costa Lima (1931) as a potential threat to Brazil's developing banana industry. None of these have been recorded as economic pests of bananas in Central America. Johnston (1932) states that occasionally peel damage of caterpillar origin has occurred throughout banana cultivations in Central America and Jamaica in the past. More recently, however, the tortricid *Platynota rostrana* (Walker) was reported by Roberts (1956) as one species of economic importance to banana growers in Central America because of its peel-feeding activities.

While this is the first known record for *P. rostrana* in Honduras, it is nevertheless indigenous to Latin America and the Caribbean area. Sasscer (1911), Otero (1935), Walsingham (1914), and Capps (personal communication, 1958) report that its tropical distribution extends through Mexico, Guatemala, Panama, Colombia, Venezuela, Brazil, and the islands of Cuba, St Vincent, Jamaica, Grenada, San Domingo, Puerto Rico and Trinidad. A rather general feeder, its host plants include the Malvaceae reported by Heinrich (1921), lima beans (Bruner, 1931), guava (Otero, 1935), citrus and eucalyptus (Sasscer, 1911). Furthermore, Capps states that specimens of *P. rostrana* have been collected by quarantine inspectors from the debris of banana shipments arriving in the United States; but this is believed to be the first reported incidence of its economic importance to banana fruit in the field.

The life cycle of *P. rostrana* was investigated in the laboratory. These findings helped to interpret field observations and determine economical methods of chemical control.

MATERIALS AND METHODS

Adult moths and caterpillars collected from hanging fruit in the field were brought to the laboratory for study. The caterpillars were reared individually in 250 ml beakers provided with a lid of muslin secured tightly

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† The Tela Railroad Co. is a subsidiary of the United Fruit Company.

with a rubber band. Discs of paper towel cut to fit snugly in the bottom of the beaker prevented the food from sticking to the glass and provided a wettable surface to maintain humidity. Fresh one- to two-month-old fingers of green fruit were cut into two-inch lengths and put in each beaker as food. A 'step' was cut into the pulp surface of the banana pieces or the peel was grooved deeply to produce two adjacent surfaces between which a web could be spun. Some pieces included the dried flower ends and no groove was necessary. Fresh food of this type was supplied every two weeks.

Adults were kept in similar cages and were provided with 'bee honey' as food spread on a 9 cm filter paper disc in the bottom of the beaker. The captured females laid egg masses containing from 46 to 69 eggs each. Caterpillars hatching from these masses were transferred to and reared individually on pieces of green banana or on succulent hermaphrodite flowers.

A binocular microscope, provided with a calibrated ocular micrometer, was used to obtain measurements of head capsule widths. These measurements represented the widest part of the capsule and were taken on all reared material.

RESULTS

As indicated in *Table 1*, approximately 45 days were required for the development of an individual from the moment of oviposition to adult emergence.

Table 1. Duration of immature stages, and larval instar head capsule widths, of P. rostrana

	Egg	*Larval instars* 1	2	3	4	5	6	*Pupa*	*Total*
Duration, days	8·1	6·6	4·0	3·3	4·0	4·3	8·0	6·6	44·9
Head capsule width, mm (*with Standard Deviation*)		0·2	0·272 ±0·05	0·394 ±0·11	0·531 ±0·13	0·815 ±0·10	1·288 ±0·13		

In all but six cases, the larvae passed through six instars before pupating. The exceptions were caterpillars that required only five instars to reach pupation. While the duration of the latter's development was equivalent to that of individuals passing through six instars, head capsule measurements indicated that the third or fourth instar was skipped. No differences were discerned in the time required for development of males and females.

When newly hatched larvae were transferred to rearing cages, they would actively reconnoitre their surroundings for a suitable location in which to establish themselves. Those placed in cages containing a slice of banana fruit with an intact flower end tip, always settled in the region of the flower. In cases where no flower end tip was available, larval mortality was very high during the first instar.

Following each moult, the larvae consumed all of the exuviae except the head capsule. The lack of this dietary amendment did not interfere with normal development when, on five occasions, exuviae were removed before the larvae had an opportunity to devour it.

Since the size of the food restricted the potential surface feeding area, larvae reared on pieces with the pulp surface exposed fed on and tunnelled into the pulp. The caterpillars always kept tunnels and peel-feeding areas clear of refuse. Faecal pellets were forcibly discharged during defaecation and either fell to the cage floor or became entangled in the web. Moulted head capsules most often were deposited in the periphery of the web but occasionally were dislodged by the activity of the caterpillar and fell to the cage floor.

The initiation of the moulting period was indicated by simultaneous paling of the cephalic margin of the prothoracic shield and caudal margin of the head capsule. The exoskeleton fractured transversely through this region, permitting emergence of the next instar individual. During the terminal moult prior to pupation, the head capsule fractured longitudinally along the dorsal midline. The quiescent pre-pupal period of 24 hours duration was accompanied by cessation of feeding and thickening and shortening of the body. Usually pupation occurred in the feeding area but occasionally the caterpillar would leave the food and pupate elsewhere in the cage. Eye spots were apparent within 72 hours after onset of pupation.

DISCUSSION

The gravid female moth in nature will deposit its egg clusters on the leaves, leaf petiole, pseudostem, or on the fruit of the banana plant. Egg masses were characteristic of Tortricids, the flattened discoid eggs overlapping each other like fish scales. Masses consisting of 12 to 73 eggs have been observed in the field. The masses are covered by a smooth coating of transparent protective 'varnish' and at deposition are pale green, becoming darker green as the embryos develop. Hatching occurs 7 to 9 days after deposition, when the first instar caterpillars chew through their egg shells and emerge. Larvae are not gregarious and quickly crawl up and away from the egg mass or, producing a silken thread, drop from the site of the mass to some surface below. The location of the egg mass in relation to a hanging stem of fruit at the time of 'threading down' influences the occurrence of stem infestations. However, air movement, such as a breeze or wind gust, in the plantation at this time also influences the dispersal of the larvae.

Laboratory observations suggest that the young larvae prefer the flower end tips of the fingers. Neither the caterpillar nor its damage was encountered on the peel of fruit less than two weeks old and it is possible that the larvae were still feeding in the flower ends. *P. rostrana* seeks any protected area that offers two surfaces which can serve as attachments for a web. Second instar larvae have been collected in the field by splitting the style to expose the caterpillar within that hollowed floral part. The only indication that the dried flower end was inhabited was the presence of faecal pellets fouling the flower end tip.

Frequently, small peel scars are found near the tip of the fingers of two- to four-week-old fruit. These scars are produced by young caterpillars which, while still confined to the region of the flower, have exhausted the available food and have commenced to feed on the peel. Older caterpillars (third to sixth instar), preferring the shelter provided by closely packed

fruit, are invariably found in the interfinger areas of stems more than one month old. Here the natural protection is enhanced by the weaving of a strong-fibred web binding adjacent fingers together and covering the surface feeding areas. The caterpillar may spend the remainder of its immature development and pupate in this one location. Nevertheless, the likelihood does exist that one caterpillar may move to new feeding sites on the same stem of fruit. This possibility was implied on several occasions when head capsules taken from different feeding sites of one stem provided, on measurement, a complete series representing the third to sixth instar.

Larvae have never been encountered tunnelling into green hanging fruit in the field because latex oozing from the feeding wound serves as a deterrent to deeper penetration. *P. rostrana* is not a superficial feeder but is restrained by latex discharge and as the wounded surface heals over, a brown, sunken region containing scab-like areas of dried latex is produced (*Figure 1*).

Figure 1. Paired fingers spread to expose interfinger area and typical peel scab damage (right) which may rema in concealed during cursory observation of undisturbed, compact bunch (left)

The presence of the ' scab ' and a web characterize Tortricid peel damage and distinguish it from that of other peel-feeding caterpillars encountered on banana fruit in Central America.

NATURAL AND CHEMICAL CONTROL

Otero (1935) has reported that species of the Braconid *Apanteles* and the Eulophid *Sympiesis* are parasitic on *P. rostrana.* In Honduras, the Reduviid *Castolus plagiaticollis* Stal. has been observed stalking *P. rostrana* on hanging fruit in the field. Captive *C. plagiaticollis* caged with larvae in the laboratory did not require a period of starvation as a stimulus but fed upon this prey without hesitation.

It is not uncommon to find at least one nymph or adult Reduviid on almost every stem in some undamaged plantation areas. On several occasions, infested areas have been singularly devoid of this predator and, although it feeds on a variety of prey, its absence has undoubtedly contributed to the increase in the caterpillar population and peel damage.

Chemical control investigations have been conducted with three levels of Perthane* wettable powder formulations to compare their effects on *P. rostrana* infestations in experimental plots. Sprays containing 1, 1½, and 2 lb actual Perthane in 100 gallons of water were applied twice at 14-day intervals by ground equipment to all hanging fruit in the treatment plots. All treatment levels were equally effective and significantly better than controls.

Applications of Bordeaux 5–5–50 and of 0·375 lb actual dieldrin in 100 gallons of water were made in other tests and neither was effective in control of *P. rostrana*.

SUMMARY

The Tortricid *Platynota rostrana* (Walker) is reported as a peel-feeding pest of banana. It requires approximately 45 days to develop from oviposition to adult, passing through six larval instars before pupation. Laboratory and field observations indicate that the caterpillar can infest fruit of all ages but since it is confined to the flower end tip of young fruit, damage to very young stems will not be visible to the casual observer. More mature compact stems, with extensive interfinger areas available to protect larval activity, are subject to attack by older instars. Damage is described and the performance of the predatory Reduviid *Castolus plagiaticollis* Stal. and several chemicals in the control of the pest are discussed.

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* 1,1-bis (*p*-ethylphenyl)-2,2-dichloroethane, Rohm & Haas Co.

Speckling of Banana Fruits in Central America Caused by Deightoniella torulosa *(Syd.) Ellis*

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It is still true, as stated by Wardlaw (1935), that ' the information on the subject of banana fruit-spots is scanty '. Several apparently different kinds of spot have been described, but in a few cases only has the cause of disease been discovered. Thus, according to Johnston (1932) and Johnston and Slocum (1932) a disease described as ' the fruit-spot ' and attributed to physiological causes has appeared in Jamaica, Central and South America. Wardlaw (1934) has described a ' pitting ' disease, caused by *Piricularia grisea*, and several spotting diseases occurring in Trinidad. Several fungi appeared to be associated with these fruit-spots in a primary or secondary capacity but no specific relationships were made out.

During the rainy seasons in Jamaica, a fruit-spot disease popularly described as ' speckle ' often results in appreciable quantities of unmarketable fruit. Recent studies demonstrated that speckle is caused by the fungus *Deightoniella torulosa* (Syd.) Ellis (Meredith, 1960 a, b, 1961 a, b, c, d). A speckling of Gros Michel bananas has been recorded in Central and South America and, in 1953 and 1954, many thousands of bunches grown in Honduras and Guatemala were rejected because of this blemish (Anon., 1955). On a recent tour of Central America the writer was able to make some observations on speckling and to compare the disease with that in Jamaica. These observations are described in the present paper.

SYMPTOMS OF DISEASE

A brief description of speckling as it occurs in Central America has been given as follows (Anon., 1955): ' Speckling consists of red-brown spots on the surface of the peel which are flush with the surface or only slightly raised and are usually surrounded with a water-soaked halo. Such spots do not increase in size when ripened at 64°F or 74°F from color index 1 to color index 7. The water-soaked area around each speckle which at color index 1 appeared as a green halo is more difficult to observe at color index 7, having gradually lost its outline with the yellowing of the fruit. These findings indicate that speckling is not the fruit-spot discussed by Johnston . . . with which speckling was originally confused. Johnston also found that spots red-brown in color with a green halo and less than 1/16 inch in diameter did not increase in size and that the halo disappeared when the fruit turned yellow . . . It is obvious that the speckling which is of great concern at present is the very spot which at Johnston's time

(1932) was of little importance . . . On the other hand, the Johnston fruit-spot, which is larger and depressed, has not been observed to any great extent . . . Practically all stems of speckled fruit are more heavily speckled on the side exposed to the atmosphere than on the side sheltered by the plant . . . Also, a finger covered by another exhibits less speckling than those exposed to the atmosphere . . .'

From the above description it seemed likely that speckling in Central America is identical with that in Jamaica which has been described in detail elsewhere (MEREDITH, 1961 a). This was partly confirmed in the present investigation by examining specimens collected at Armuelles and Changuinola, Republic of Panama and at La Lima, Honduras: varieties examined with speckle included Gros Michel, Lacatan, Valery, Cocos, Giant Cavendish and Jamaica Unknown (? Robusta). In every case symptoms corresponded closely with those on Lacatan, Robusta and Gros Michel bananas in Jamaica. In several small spots it was possible to observe the expended conidium of *D. torulosa*, with its attached appressorium, lying on the surface of necrosed epidermal cells (see MEREDITH, 1961 a).

PATHOGENICITY TESTS

Small-scale inoculation experiments were set up in the laboratory using an isolate of *D. torulosa* obtained from decayed cushions* (cushion- or crown-rot). Segments of healthy, spot-free peel measuring 3·0 cm × 3·0 cm × 5·0 cm were cut from surface-sterilized green bananas (Lacatan, Gros Michel and Valery). A suspension of conidia of *D. torulosa* was prepared in sterile distilled water and one drop pipetted on to each peel segment. The segments were incubated at 62°C inside damp chambers. Controls were provided by segments treated with sterile distilled water only. After 30 h many minute reddish-brown spots, each having a characteristic dark green halo, appeared on all inoculated replicates; controls remained free from spotting. After 48 h the experimentally induced spots were identical, both macro- and micro-scopically, with those occurring under natural conditions. Details of spore germination and infection by *D. torulosa* were similar to those already described (MEREDITH, 1960 a, 1961 a).

FIELD OBSERVATIONS

Several plantations near La Lima were visited with the object of comparing the incidence and distribution of speckle with that in Jamaica. It was learnt (United Fruit Co.—personal communication) that, during recent years, very few instances of severe speckling had been observed. A similar low incidence of badly affected fruit was noted in the present survey, most bunches examined being given an index number of less than 1 (slight—see MEREDITH, 1961 b). Exceptions were found in certain plantations where under-tree irrigation is practised. Almost without exception, relatively low-hanging bunches (6 to 9 ft) were more severely affected (index 1 to 2·5) than those borne at greater heights (index rarely greater than 1). A similar situation exists in Jamaica, and it has been suggested (MEREDITH, 1961 c)

* The terminology of WARDLAW (1935) is used throughout this paper: 'The individual banana fruit may conveniently be described as a " finger ", and its short stalk as the " finger-stalk "; where several " finger-stalks " meet to form a " hand ", a crescentic " cushion " (sometimes referred to as the " crown ") is formed. These cushions project from the " main-stalk " of the whole bunch '.

that low bunches are usually more severely affected than higher ones because of the limited height to which air-borne conidia of *D. torulosa* are carried.

Cursory observations suggested that the varieties commonly grown in Central America, namely Gros Michel, Cocos and Lacatan, and several varieties under investigation, for instance Jamaica Unknown, Giant Cavendish and Valery, are all to some extent susceptible to infection by *D. torulosa*. A more detailed assessment must be made to evaluate the relative susceptibilities.

DISCUSSION

Formerly it was not known whether 'speckle' in Central and South America is identical with 'speckle' in Jamaica. Symptomatological studies and pathogenicity tests described here suggest strongly that they are identical, the causal organism being *D. torulosa*. Several types of fruit-spot, to which names such as 'speckle', 'freckle', 'flecking', 'the fruit-spot', 'pitting', 'blotch' and 'thrips injury' have been given (JOHNSTON, 1932), are described in the literature. To avoid possible confusion, it is suggested that the term 'speckle' should be used exclusively for the type of *Deightoniella* infection described here and elsewhere (MEREDITH, 1960 a, 1961 a). If there is any doubt concerning the identity of a fruit-spot disease, a simple pathogenicity test with *D. torulosa* will provide true speckle for comparison, usually within 48 h under laboratory or field conditions.

In Jamaica, aerobiological studies have provided useful information about the epidemiology of speckle (MEREDITH, 1961 c, 1962). A similar approach may contribute appreciably towards a fuller understanding of the varied incidence of disease in Central America and elsewhere.

SUMMARY

Observations in Central America suggest that a banana fruit disease known as 'speckle' is identical with a disease having the same name in Jamaica. The causal fungus is *Deightoniella torulosa* and details of spore germination and infection are similar in both regions.

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Book Reviews

THE SOIL UNDER SHIFTING CULTIVATION

P. H. Nye and D. J. Greenland. *Technical Communication No. 51*, Commonweath Bureau of Soils. Commonwealth Agricultural Bureaux, Farnham Royal, Bucks., 1960. 156 *pp.* (16 plates) 20*s*

This book is a comprehensive, very informative discussion of the fertility of freely draining soils in sub-humid to humid tropical regions in relation to short-period cropping and natural regrowth. It incorporates the results of recent researches in Ghana, and much other literature is critically digested; there are about 330 references.

The authors set out to make a quantitative examination of this complex subject, because this was ' the surest way of evaluating the many assertions about the effect of this or that factor on the fertility of the soil '. They are therefore concerned with various sorts of field data and with the application of chemical analysis. It will be seen that there is now much relevant quantitative information on potassium, calcium, magnesium, nitrogen and soil organic matter, but that there has been a lack of satisfactory methods for studying the availability of phosphorus in the soil, which has limited progress.

The Introduction gives a general explanatory account of the practices which the authors include under the term ' shifting cultivation '. It emphasizes that the more systematic sort of practice, which some agriculturists in Nigeria have preferred to call ' rotational bush-fallowing ', and which has been developed with experience and care, can be an excellent system of farming, especially where the fallow growth is of forest species and possibly also where it is of elephant grass. Attention is also drawn to the problems of *Imperata* infestation and of the lowered fertility when forest regrowth is replaced by savannah, where the better practices are not known or are no longer kept up.

In Part I the fallow period is considered mainly from the point of view that the beneficial changes brought about in the soil are ' closely linked with increases in the soil humus, which helps to hold the exchangeable cations added to the topsoil in the nutrient cycle, stores important reserves of phosphorus and sulphur, and above all is the sole reservoir of nitrogen '. The quantities of nitrogen, phosphorus, potassium, calcium, and magnesium contained in an acre of vegetation are compiled from studies of three forest sites (including two at Yangambi) and a patch of savannah woodland and one of *Imperata* grassland, and from several less complete studies. These quantities are compared with data for the nutrients stored in the top foot of soil. Details are given for the quantities of nutrients added annually in forest litter, and also, for one forest site, for the amounts of nutrients returned to the soil in rain wash from the leaves. It is shown that the amount of leaf fall in tropical forests is about 4 tons of dry matter per acre per annum,

whilst the amounts of dead wood and roots are rather less. The authors remark later (in Part II), that estimates of additions of plant debris more than ten times too great have been current, and that this is one reason why the rates of decomposition of litter and soil organic matter in the tropics have been greatly exaggerated (because the steady state is soon reached under forest or savannah where, over a period of a year, addition and loss of organic material are equal).

It has not been possible to deal so effectively with the question of the relative proportions of each nutrient that are absorbed from the topsoil and subsoil during the growth of the fallow, and the amounts that are thus ' pumped up ' to the surface. It is surprising that particular mention is not made of the apparently clear conclusion from NYE and HUTTON's study of an elephant-grass cover at Benin that a great deal of potassium had been pumped up from below, giving a marked increase in exchangeable potassium in the top foot of soil whilst a large amount was also stored in the stems and leaves.

Part II deals with the cropping period. First the effect of clearing and burning is shown to be chiefly the addition of nutrients and the raising of the pH, and then the decline in fertility under cropping is very fully examined. Some writers have thought that the practice of leaving the land fallow after about two or three years cropping showed that fertility declined at a very great rate in the tropics, and that a piece of land is abandoned because a worthwhile yield can no longer be obtained from it. Results quoted here show that the decline in yields is gradual if cultivation is continued for a long time, and that small additions of nutrients in refuse, animal manure, or fertilizer serve to maintain them at quite a good level. The shortness of the cropping period is shown to be a matter of necessity if vigorous regrowth of woody species is to be ensured in the forest belt, whilst in land invaded by *Imperata* it is often on account of the rapid growth of this weed; on the other hand it is concluded that phosphate deficiency is probably the main reason in savannah areas where the resting period has become short.

Three of the many interesting points in this section may be mentioned here. The authors have recognized—what has generally been overlooked—that the amounts of the nutrient cations that can be brought into solution and leached out of acid soils in cropped or fallow land are controlled by the nitrate content of the soil, because it is only above pH 6 that bicarbonates are formed in substantial amounts and can be leached; exposure of acid soils to heavy rainfall does not necessarily lead to rapid loss of potassium, calcium and magnesium, because there may be much nitrate formed in excess of that taken up by plants and soil organisms. Another useful observation is that, although much of the soil surface in savannah land is usually a bare smooth expanse between the tussocks of bunch grasses and there appears to be much run-off, the water is clear; much more thorough cultivation has to be done (to get rid of the grass) when such land is cropped than in land being cleared from forest growth, and then, if there is much run-off, soil may be lost rather rapidly. Thirdly, reference is made at several places to the repression of the mineralization of nitrogen under savannah conditions, which commonly persists for a year when the land is cropped; this does not seem to have been satisfactorily explained yet. Grain

crops are avoided in the first year, and yams are often planted, which is reasonable in view of the fact that the thorough cultivation necessary in removing grass is also particularly needed by the yam crop. A further comment may be offered here: although the yams show less pronounced deficiency symptoms than maize or sorghum would, their yield may be capable of being so greatly increased by an application of ammonium sulphate that there is here a good example of the possibility of introducing the use of fertilizer profitably into shifting cultivation; this is especially so in the areas where internal trade has made the yam a cash crop.

In Part III the authors consider the overall effects of shifting cultivation and sum up this very valuable enquiry. It appears that whilst shifting cultivation continues, the most important measures to be taken should be (*a*) the avoidance of cropping for more than two or three years at a time in forest regions (so as to allow woody species to regenerate), (*b*) early burning in savannah regions, except in special situations where a total ban on burning can be enforced, and (*c*) the increased use of phosphate in savannah regions, wherever it can be shown that the effects (immediate plus residual) are profitable.—H.V.

TROPICAL AND SUBTROPICAL AGRICULTURE

J. J. Ochse, M. J. Soule, Jr, M. J. Dijkman and C. Wehlburg. New York: Macmillan, 1961. 2 Vols. *liv* + 1446 *pp.* (illus.) £12 5*s*

As the authors of this work point out, ' there was a great need for a brief but reasonably comprehensive book on tropical and subtropical agriculture '. In this long and expensive two-volume work, the authors have attempted ' to collect together a body of information about selected tropical and subtropical crops and allied subjects '. The senior author, Dr Ochse, is well known for his excellent books on the fruits and vegetables of the Netherlands East Indies, where he was Head of the Division of Agriculture. His son-in-law and co-author, Dr Dijkman, also worked in Java, as did Dr Wehlburg. Dr Soule is Associate Professor of Fruit Crops at the University of Florida. Working together in Florida during the past ten years, they have compiled a great deal of information, much of which will be of value to the tropical agriculturist. Nevertheless, as we shall show, there are grave deficiencies.

The first 288 pages are devoted to giving a broad background in climatic factors, formation of soil, soil fertility and soil management. Then follows a long chapter of 80 pages, which is devoted mainly to plant propagation and crop improvement. The remaining three quarters of the book gives an account of individual crops. The scientific name of the crop is followed by a list of its regional and popular names in English, Spanish, Dutch, German, French and Portuguese. The description of each crop follows a similar pattern: general information including world production, botany, botanical description, varieties, breeding and selection, climatic and soil requirements, culture, harvesting, processing and uses. In the case of some of the minor crops, some or all of these sections are combined. The book concludes with a glossary and subject indices.

In Part I of the book the ecological zones and systems of agriculture of the tropics are given scant attention. Shifting cultivation, here called ' patch, *ladang* or *kaingin* culture ', is dismissed in less than one page and the impression is given that forests are cut down and after one to three seasons of cultivation, the land reverts to *cogon* (*Imperata cylindrica*, more widely called *lalang*). The areas are then lost to agriculture until ' the grass can be ploughed out and destroyed by power equipment '. Although this may be partly true of tropical rain forest areas, it certainly is not true in savanna and grassland regions. Surely this most important system of tropical agriculture needs fuller and better treatment. With the all-embracing title of the book it is somewhat surprising that no mention whatsoever is made of animal and grassland husbandry.

Chapter 2, of 64 pages, attempts a highly technical review of literature on rock-weathering and soil formation. It is over-loaded with confusing detail, as in lists of the composition and supposed resistance of rock minerals, soil-moisture conditions, and stages in the development of soil materials according to concepts that some soil specialists have found unacceptable. No useful or clearly recognizable picture of any of the main soils of the tropics emerges. The question must be asked whether it is possible to interpret correctly much of the earlier chemical work on tropical soils, in which the morphology of the soil profile and of the landscape were not adequately studied and the terms ' laterite ' and ' laterization ' were used in such conflicting senses by different workers. Here (on page 69) there is brief mention of a general grouping of soil profiles into mature, truncated and undeveloped types—a basis for a morphological classification—but instead of truncated soils being recognized as including generally superior soils on slopes, sometimes having rotting rock at no great depth, the comment is that they result from interference with the natural cover of vegetation, especially under ' a shifting or nomad form of agriculture '.

Chapter 3 gives a long account of basic research on clay minerals and cation exchange, a review of the physical properties of soils, and some elementary facts about soil organisms and organic matter; these are sound in content and clearly written, but cannot be expected to be of much interest to the general reader.

Chapters 4 and 5, on ' Soil fertility ' and ' Soil management ', are of a general introductory nature, and refer mainly to manuring, soil conservation, and the use of ground covers and shade trees in plantations of permanent crops. The writer of these chapters does not give the impression of accepting the general picture of tropical soils given in Chapter 2—that they are subject to extremely rapid loss of humus and nutrients and the formation of laterite hardpans. But detailed information on the results of experiments and laboratory studies on soil fertility in the tropics is lacking—nor is there much later in the book, in relation to particular crops.

Turning to the individual crops, the authors state that ' the list of plants which could have been included is almost endless; therefore it was necessary from the beginning to select certain ones for treatment. These were chosen partly on the basis of their world-wide importance and partly to afford representation to different areas of the tropics and subtropics '. The treatment of those included varies enormously. Thus of the 950 pages devoted

to crops, citrus occupies 122 pages, other fruit crops 237 pages (including such unfamiliar fruits as *lovi-lovi*, *rukam*, *grumichama*, *pejibaye*, *salak* and *longan*), coffee, cocoa and tea 143 pages, rubber 82 pages, sugar-cane 57 pages, and bananas 28 pages. No other crop exceeds 20 pages of text, except quinine which is given 20 pages plus 5 pages of references, although it is admitted that it is now of little importance, while crops such as coconuts, oil palm, cotton and tobacco are given less space. A great many tropical and subtropical crops are left out completely, some of which are of very considerable importance, such as all the root crops, pulses and vegetables. In the case of sorghum no mention is made of SNOWDEN's classification, nor of the breeding work of DOGGETT and others in Africa. *Eleusine coracana*, an important crop in parts of Africa, is dismissed in two lines by stating that it is ' cultivated extensively in China and India '. Bulrush millet (*Pennisetum glaucum*), here called ' pearl millet or Indian and African millet ', is given similar treatment, as it is merely stated that ' it is planted for forage and grain in warm countries '.

Lack of care in the preparation of the book is evidenced in the historical remarks that are made about various crops. The first shipment of palm oil to England was not made in 1790, but in the sixteenth century, and shipments to Liverpool were fairly regular from 1772. BLIGH, who arrived in Jamaica in 1793 and not 1791, was not the first introducer of *Saccharum officinarum* to the West Indies but had been preceded by an introduction to Martinique. It is misleading to say that VAN HOUTEN ' discovered ' a way to produce a ' new product ', defatted cocoa, in 1828 since references to this process had been published in France in 1763 and in Italy in 1768. It would be interesting to know the evidence that cloves ' early became widely distributed throughout the Far East ', since they are usually regarded as strictly confined to the Moluccas until their introduction to Mauritius in 1770 (1772, the date given in this book, represents a second introduction).

Perusal of the book shows that the authors are well acquainted with Indonesia and tropical and subtropical America, but their lack of practical knowledge of Africa is a serious disadvantage.

There are two coloured plates, one showing the stages in the ripening of a banana and the other, of fermented cacao, will be familiar to many readers. The 283 black and white illustrations are of varying quality; we would have difficulty in recognizing sesame from the drawing on page 1091.

The long subject index of 86 pages is difficult to follow. Under each letter there are two sections, the first being devoted to the ordinary common and proper names and the second to scientific names. All diseases are included under this head and all pests under Insects; although one is left to discover this for oneself.

While the work contains much useful information, it can be seen from the above that it cannot be recommended as a comprehensive and up-to-date textbook of *Tropical and Subtropical Agriculture*. There are too many gaps. The very high price can hardly be justified and will put it out of reach of all but the most affluent.—G.B.M., J.W.P., and H.V.

THE PINEAPPLE

Botany, Cultivation and Utilization

J. L. Collins. London: Leonard Hill, 1960. *xvii* + 294 *pp.* (illus.) 60*s*

This is the second in the series of World Crops Books under the general editorship of Professor Nicholas Polunin published by Leonard Hill. The author, Dr J. L. Collins, was formerly Geneticist and Acting Director of the Pineapple Research Institute, Hawaii. As might be expected, we are presented with an authoritative account of all aspects of this important and interesting crop.

Part I deals with the history, taxonomy, origin, ecology, morphology and anatomy, cultivars, and regions of cultivation, with the longest chapter being devoted to cytology, genetics and breeding. Part II gives details of the cultivation of the crop and includes an account of the cultural methods in the various producing countries and of the diseases, pests and abnormalities. Part III deals with utilization; the chapter on fruit preservation and uses includes a number of recipes of interest to the housewife; this is followed by an account of the by-products and concludes with a chapter entitled ' More Pineapples for More People '. There is a bibliography of 8 pages and an adequate subject and author index.

Pineapples were widely distributed and had long been cultivated in the New World tropics before Columbus first saw them growing in Guadeloupe in 1493. For the next 400 years they were disseminated to many tropical and subtropical countries, including the expensive production in the heated greenhouses of the nobility of Europe. The period from 1900 has seen the industrial development of pineapple cultivation and canning on an increasing scale, being pioneered by Hawaii. The future expansion of the industry will depend upon the development of larger markets for the processed fruit.

As with so many other crops of the tropics, the countries in which the maximum economic production takes place are on the opposite side of the world from where the crop originated.

The detailed documented account of the origin, history and migrations of the most important cultivar ' Cayenne ' is very interesting. Five plants were taken from French Guiana to France in 1820. It reached England about 1835, from where it was distributed to countries in both hemispheres. It was taken to Hawaii in 1885 and from there it has been distributed to many countries during the last 40 years.

In the first paragraph of the introduction we read that the pineapple ' symbolizes balmy tropical lands and the legendary leisurely life on tropical islands. This aura of exoticism has continued to surround the pineapple from its discovery to the present day with the result that the fruit of this plant may be considered as an orchid among the fruits of mankind '. Fortunately, this style of writing is not repeated elsewhere in the book, which is clearly written and well produced. The drawings and photographs are of a high standard.

This book is a very welcome addition to the small but growing literature on tropical fruits and is warmly recommended. It is likely to be the standard work on the pineapple for some time to come.—J.W.P.

COCOA

D. H. URQUHART. London: Longmans, Green, 2nd ed. 1961. *xxv* + 293 *pp.* (illus.) 40*s*

The first edition of *Cocoa*, published in 1955, was well received by planters, agricultural officers and research workers alike, since it met a long felt need for an authoritative, modern textbook on this important tropical crop. Much of the text has been re-written and new chapters added in the second edition, the purpose of which, the preface states, ' is to review recent progress and bring the work up to date '. The manuring of cocoa forms the subject of a new chapter; regrettably, the account of manurial experiments conducted in Trinidad stops short at 1955, and the interaction between shade and nutrition, established by fundamental researches in that territory, receives inadequate attention. The chapters dealing with the establishment and maintenance of the cocoa plantation have been augmented by a short chapter on planting material, in which the breeding programmes of WACRI and ICTA are reviewed. As far as the ICTA programme goes, the reader might gain the impression that breeding was restricted to the production of crosses between Scavina and Trinitario parents. Some misinformation is given on page 84 where (*i*) the Amazon varieties are said all to be cross-compatible, and (*ii*) ICS 46 and ICS 47 are given as self-compatible clones; and more on page 85 where ICTA is proclaimed a source of planting materials (we hope Central American planters will not interpret this too literally). The book could undoubtedly have been made more up-to-date had the author invited statements from the main research stations on the position of their researches. The number of appendices has been increased from eight to eleven, but the useful glossary of terms which appeared in the first edition has been deleted, though reference to a glossary appears in the index. Appendix III on planting distances and plant density could be improved by giving all data in both imperial and metric units. Apart from these minor defects, the second edition, as excellently illustrated as the first, can be warmly recommended to all whose interests lie in cocoa production.—F.W.C.

COIR—ITS EXTRACTION, PROPERTIES AND USES

Council of Scientific and Industrial Research, New Delhi. 54 *pp.* (illus.) *Rs* 6.00 or 10*s*

The title of this short book should really read ' Coir in India ' for apart from some mention of Ceylon it deals almost exclusively with the industry in India. The result is that in describing fibre extraction only the traditional methods of retting are dealt with, purely mechanical processes used in other countries being barely mentioned.

The spinning, weaving, dyeing and printing of coir yarn as practised in India are dealt with in some detail and specification and trade names are listed. A short chapter deals with marketing and trade and a bibliography of 49 references is given.

The section on other uses of coir is disappointing. A fair number are given, very sketchily, and there is no attempt at a critical evaluation of the various possibilities. This book can have only a local and limited appeal.—D.B.M.

THE WAGENINGEN RICE PROJECT IN SURINAM

A Study on the Development of a Mechanized Rice Farming Project in the Wet Tropics

TH. P. M. DE WIT. 'S-Gravenhage: Mouton, 1960. 293 *pp.* (illus.)

From time to time since 1920 attention has been given to the possibilities of mechanization of rice cultivation in Surinam. It was not until 1949, however, that a determined effort was made to develop land on a large scale for mechanized rice production. Under the direction of The Foundation for the Development of Mechanized Agriculture in Surinam, the Wageningen Rice Scheme was started with the main object of settling Dutch immigrants, stimulating the influence of agriculture in that area, and generally improving the state of food production in the Dutch territories.

This publication attempts, in a concise manner, to place on record the experience of the project in the important first ten years of its existence.

The author has undertaken the study in a systematic manner, paying due attention to such important local factors as climate, soil, vegetation, the history of the country, its population and economic structure and showing how they play a major role in influencing the work done and the results obtained. The chapters on surveys, planning and execution of the reclamation, drainage and irrigation works are well done. The serious problems and pitfalls of planning with inadequate local data are clearly brought out.

On the operation of the project, the author deals fully with mechanical field preparation, planting, harvesting and water control, including the problems encountered when new areas are entered. Other important agronomic operations such as manuring, and control of weeds, diseases and pests are given fair treatment. The study is carried up to the stage of processing of the crop for marketing.

The author is obviously not fluent with English and in many instances the presentation is lacking in clarity. There are some grammatical and spelling errors, and such abbreviations as Na-arsenite, Mg-clay, NH_4 fertilizer, etc., although very convenient for notes, do not make good reading. The illustrations are excellent and the printing is good.

This publication is of considerable value coming at a time such as this when so many of the underdeveloped territories of the tropics are becoming increasingly aware of the need for opening new land for development. The results of investigations into the agronomy and other aspects of rice production in the area also form an important contribution to existing knowledge on the subject. Anyone concerned with planning and execution of any agricultural development scheme in the tropics will do well to read this publication.

There are many undertakings of a similar nature which have been or are in existence, but whose experiences unfortunately have never been or only partly recorded. In this respect also the author is to be complimented for his efforts in carrying out this important study and making the findings available.—L.G.C.

PLANT ANALYSIS AND FERTILISER PROBLEMS

Edited by W. Reuther. American Institute of Biological Services, Washington 6, D.C.: The Lord Baltimore Press, 1961. *xv* + 454 *pp.* $8.00

This book contains the text of thirty papers and one discussion, part of the proceedings of the Third Colloquium on Plant Analysis and Fertiliser Problems which was held in connection with the Ninth International Botanical Congress which took place at Montreal, Canada, in August 1959. The publication of this book is sponsored by the American Potash Institute and it is dedicated to Dr T. Wallace, Emeritus Professor of Horticultural Science, Bristol University. Papers were presented from eleven countries, fifteen from the United States of America, three from France, two each from Israel, Japan, South Africa and U.S.S.R., and one each from Brazil, Canada, Congo and the U.K.

It is impossible in the limited time of seven three-hour sessions, which constituted the colloquium, to present an unbiased picture of the state of knowledge on plant analysis and its relationships with fertilizer application. However, the division of the subject into two main groups, each subdivided into three sections, has done much to reduce over-emphasis on particular crops or geographical areas.

The majority of publications on foliar diagnosis pay little or no attention to the problems of sampling errors, both in the field and in the laboratory, and analytical errors. Invaluable data on these factors are included, however, in several of the papers presented, and the importance of quoting results in either a standardized form, or in sufficient detail to enable other workers to transform published data into units used by themselves, was emphasized.

The subject matter of the papers varied not only in crop and area but ranged from a consideration of the use of foliar diagnosis in making recommendations for large areas in Brazil to a detailed amino acid analysis of strawberry plants. No attempt will be made here to evaluate each paper.

The majority of the papers have adequate summaries. Considering, however, that twenty eight papers were in English it is a grave fault that only one of these papers contained a summary in another language (French). Two papers were in French but neither has a summary of any kind. In a publication of this nature every paper should have a summary in an alternative language. Only two papers were without a bibliography, the rest being supplied with bibliographies of varying lengths and value. It is unfortunate that to the majority of scientists outside Russia references in Russian script are meaningless.

This book, well bound and printed on good quality paper, is a valuable compilation serving to remind its readers not only of how far we have come but also how far we still have to go in the study of the mineral nutrition of plants. The fourth colloquium in this series is being organized in connection with the International Horticultural Congress to be held in Brussels in 1962. The results of its deliberations will be eagerly awaited.—G.K.M.

FARM IMPLEMENTS FOR ARID AND TROPICAL REGIONS

H. J. Hopfen. *F.A.O. Agricultural Development Paper No. 67.* Rome: F.A.O., 1960. *viii* + 157 *pp.* (illus.) Also available in French and Spanish. $1.50 U.S. or 7*s* 6*d*

The author describes the construction and operation of a fair range of what must be considered ancient agricultural tools and implements. In the introduction he indicates that there are many areas where the agricultural community has yet to advance to the stage of using these simple tools to assist in improving their production. He attempts to justify this publication on the ground that the promotion of agricultural mechanization should be gradual and made to follow a logical sequence, especially in uneducated communities where the need for simplicity of operations is so much more critical.

The content is well set out, beginning with tools and implements for land preparation and moving on to the operations of planting, after-cultivation, plant protection, harvesting and processing, and finally dealing with handling, transporting and workshop equipment. The illustrations are excellent.

Improvements in the agriculture of tropical and arid areas should lead to increases in total production in order to meet the present unsatisfied demands. They should also ensure that each unit of labour is made to produce considerably more than it has done up to now, if the wish for the raising of standards of living in rural communities is ever to be realized. The use of improved, modern and efficient machinery and power units is of paramount importance among methods directed to this end. It is in this light that one hopes the usefulness of this publication will be of very short duration. It will, however, continue to serve as a good catalogue of museum items dating back to biblical times.—L.G.C.

SYMPOSIUM ON MECHANICAL CULTIVATION IN UGANDA

Edited by J. L. Joy. Kampala: Uganda Argus, 1960. 170 *pp.* 15*s*

This publication represents a collection of papers presented at a symposium two years earlier. The title might be misleading in that the subject matter is not restricted to the mechanization of the cultivation operation. The symposium treats mechanization only as a means of reducing production costs and increasing farm incomes. Apart from treating the subject of mechanization in agriculture up to the stage that it has progressed in East Africa, the symposium deals with other problems of crop production and those of a socio-economic nature related to mechanization.

The problems experienced in introducing machinery to attempt to reduce the burdens of crop production operations in areas with cheap and unskilled labour make interesting reading and the first part of this volume is devoted to giving accounts of these. The second part deals with technical, organizational and costing aspects. A third section is devoted to an appraisal of the information available, summarizing it and making general

recommendations with the hope that the Government or other policy-making bodies will take some notice of them.

The symposium has shown clearly the need for considerably more information on the subject and more publications of this nature will be of enormous value to agriculture in the tropics.—L.G.C.

DIGESTIVE PHYSIOLOGY AND NUTRITION OF THE RUMINANT

Edited by D. Lewis. University of Nottingham; Butterworths: London, 1961. *ix* + 297 *pp.* (illus.) 50*s*

The particular biochemical and physiological problems connected with the ruminant have interested scientists since the middle of the nineteenth century, but some of the most outstanding advances have taken place during the last decade. For this reason the proceedings of the University of Nottingham Seventh Easter School in Agricultural Science 1960 on digestive physiology and nutrition of the ruminant are of considerable importance. Proceedings of previous Easter Schools have set an extremely high standard and this is maintained in the work under review. The proceedings have been divided into three sections: physiology in the rumen, metabolism in the rumen, and ruminant nutrition and endocrinology. Papers have been submitted in each section by authors all of whom are eminent in their own aspect of rumen research. In addition to reviews of physiological and biochemical progress considerable attention has been paid to the methodology of research on the rumen; papers are included on techniques of counting rumen organisms, the use of radio-isotopes, the use of reference substances and the measurement of flow. Most papers are followed by discussion although it is disappointing that no discussion was forthcoming after some subjects of considerable interest—for instance, that of protein synthesis in the rumen.

The text is well indexed, both by subjects and authors, and the standard of printing and binding is excellent.—M.H.B.

COMMONWEALTH TRADE 1959–60

Commonwealth Economic Committee. London: Her Majesty's Stationery Office, 1960

The dates of the title of this compact and informative publication are somewhat misleading. Most of the statistics give annual totals from 1955 to 1959 and most of the comments in the text refer to 1959 compared with 1958. Only as regards the trade of major areas in the world is there any estimate of 1960 rate. This booklet is indeed one of the series normally issued annually and could be more informatively labelled ' 1959 '.

The format combines skilful blend of commentary and statistical tables. The arrangement by Commonwealth countries makes for easy reference. It is satisfactory to see that trade with the European Common Market and E.F.T.A. countries is separately analysed—a matter of great importance politically and economically to Commonwealth countries to-day.—A.L.J.

MEAT

Commonwealth Economic Committee. London: Her Majesty's Stationery Office, 1961. 131 *pp.* 7*s* 6*d*

This publication is another in the series of reviews designed to present an up-to-date summary of world trade and consumption of meat. A discussion of the trends in production, trade and consumption in recent years is given with reasons and explanations for differences occurring wherever possible. Very full statistics are produced but, unfortunately, the sources of information are not given. It is desirable in a publication of this kind that the sources of information for this sort of data should be indicated. However, this is a very useful book of reference on the subject it covers, giving a very comprehensive treatment and also providing details of government measures affecting the production of meat in most of the countries discussed. There is little discussion of meat production in tropical countries which are of course of slight importance compared with the rest of the world at the present time.—T.R.H.

TROPICAL AGRICULTURE

The Journal of the Imperial College of Tropical Agriculture (Faculty of Agriculture, University College of the West Indies)

NOTES TO CONTRIBUTORS

These Notes replace the 'Notes for Authors' published in *Trop. Agriculture, Trin.* 1957, **34,** 315.

(1) The editors of *Tropical Agriculture* are glad to receive and consider manuscripts for publication of articles on or related to tropical agriculture. Two types of articles are acceptable: (a) original research papers, (b) review or survey articles dealing with progress in a branch of science relevant to tropical agriculture, provided that the subject matter is of more than purely local significance.

(2) It is understood that opinions expressed in articles or reviews are those of the author, and do not necessarily represent the opinion or policy of the Faculty or of any government or other authority.

(3) Authors who are government servants should include, either in the text or in a covering letter, a statement that they have the approval of their government for publication.

(4) Copyright of articles published in the Journal is vested in their respective authors.

(5) Articles should not be offered to any other journal for prior or simultaneous publication.

(6) Manuscripts are normally acceptable in English only; in special instances translation may be arranged, but such material should not be submitted without first consulting the editors.

(7) Articles should not exceed 6 000 words or its equivalent (including figures and tables). Longer articles may occasionally be considered if the subject matter is of exceptional interest and quality and if they are not suitable for sub-division.

(8) It would help if author(s) stated the approximate number of words at the end of the article.

(9) Articles should be written concisely and should be thoroughly revised before submission, the final manuscript having as few corrections as possible, preferably none.

(10) Manuscripts must be in typescript on one side of the paper only with double line spacings and ample margins. Only one fair copy, the original, is required. Sheets should be numbered consecutively.

(11) Articles should be headed in the following manner: (*1*) title, which should be kept as short as possible and be informative and specific; where necessary author(s) should give a shortened title which is to appear at the top of alternate pages of the printed article, (*2*) name(s) of authors(s) (academic degrees and honours are not printed), (*3*) a brief indication of where the work was carried out, e.g.

YIELDS OF WEST INDIAN MAIZE

H. J. Gooding

Imperial College of Tropical Agriculture, Trinidad, W.I.

If the place of work is not the present address of the author(s), the change can be denoted by an asterisk and a footnote giving the new minimal address, e.g.

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* Now at Agricultural Department, Western Region, Nigeria.

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(12) The text of all research papers, and general articles where suitable, should be concluded by a summary, followed by acknowledgements and references. The summary should be concise and critically correct of the actual contents of the article.

(13) Sectional divisions of the text should be indicated by un-numbered headings in capitals centred on the page; sub-sections by lower case headings, underlined, taken to the left margin.

(14) Footnotes (which should be avoided wherever possible) should not be placed at the bottom of the sheet, but immediately under the line to which they refer, separated from the text by two horizontal lines as shown above.

(15) Dates should be written as follows: 11 November 1960. Per cent should be written thus, not abbreviated %. Numbers up to and including ten should be written out; above ten should be given in numerals.

(16) The scientific names of organisms, other than well known plants and animals, should always be given as well as the common name. Scientific names up to generic rank should be marked for italics, e.g. *Cajanus cajan* (L.) Millsp., *Phaseolus acutifolius* Gray var. *latifolius* Freem., *Trifolium purseglovei* Gillett, *Dysdercus* spp., *Ceratitis capitata* Wied. Subsequently, if the name is repeated many times the generic name may be contracted, e.g. *T. purseglovei*, if there is no risk of confusion with names of other organisms. Note that the authority after the scientific name does not go into italics, nor does sp., spp., nor var. and that if the name of the authority is abbreviated this is shown by a full stop after the abbreviation. The scientific names of higher groups (orders, classes and families) are printed in ordinary roman type with a capital if in Latin form, but without it if in English or if used adjectivally, e.g. Leguminosae, legumes, leguminous. Vernacular names and phrases in foreign languages should also be underlined so as to appear in italics in the text.

(17) Within the text, references to literature should be denoted by giving the name of the author(s) without initials, followed by the date of the publication in parentheses, e.g. (CAMPBELL and HODNETT, 1960), except when the authors' names are part of the sentence as in 'CAMPBELL and HODNETT (1960) show that . . .' If the paper is by more than two authors, adopt the form SMITH *et al.* Personal communications should be cited thus (SMITH, personal communication, 1960) and should not appear in the list of references. Names of persons appearing in the text should be in capital letters.

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(*a*) For journals—Surname(s) of author(s), followed by initials; year of publication in parentheses (if two or more of an author's publications in the same year are cited, these should be referred to as a, b, etc., after the year); title of article; abbreviated title of journal as given in the *World List of Scientific Periodicals* and underlined to indicate italics; volume number in Arabic numerals underlined with a wavy line to indicate black type, without the prefix 'vol.'; and page numbers of article, e.g.

GOODING, H. J. (1960). 'Yields of West Indian maize'. *Trop. Agriculture, Trin.* **37,** 257–264

(*b*) For books—Surname(s) of author(s), followed by initials; year of publication in parentheses; title of book, underlined; edition and volume number if required; place of publication; publishers, e.g.

SIMMONDS, N. W. (1959). *Bananas.* London: Longmans, Green

(*c*) For bulletins, pamphlets, etc.—Surname(s) of author(s), followed by initials; year of publication in parentheses; title; abbreviated name of published series, as given in *World List of Scientific Periodicals*, underlined to indicate italics; number of Bulletin, etc., underlined with wavy line to indicate black type, e.g.

JAMISON, V. C. and BEALE, O. W. (1959). 'Irrigated corn in humid regions'. *Fmrs' Bull. U.S. Dep. Agric.* **2143**

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Department of Agriculture, Kenya. (1959). *Annual Report for 1958, Vol I.* Nairobi: Government Printer

(*e*) For anonymous publications—ANON., followed by date, etc., e.g.

ANON. (1961.) 'The form of new universities in Britain'. *Nature, Lond.* **189,** 23–24

(*f*) For unpublished theses, reports and other documents which are available for reference in a library or elsewhere—Surname(s) of author(s), followed by initials; year of writing; title, underlined; nature of document; place where it can be inspected; followed by unpubl. or ined. in brackets, e.g.

HONESS, B. L. (1960). *A preliminary ecological study of Nut-grass* (Cyperus rotundus *L.*) *under Trinidad conditions.* D.T.A. Report, I.C.T.A. Library (unpubl.)

(*g*) Undated publications—After the name(s) of author(s) n.d. is given in parentheses in place of the year of publication, e.g. SMITH, A. (n.d.).

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(20) Tables should be as simple as possible and must be of a size and form that can fit into one page of print size $4\frac{1}{2}$in. $\times$ $7\frac{1}{2}$ in. Each table should be typed on a separate sheet and

its approximate position in the text indicated. Captions for the tables should appear at the head and should be numbered consecutively in Arabic numerals. The captions should make the general meaning of the tables comprehensible without reference to the text. The units in which the results are expressed should be given at the top of each column and not repeated in each line of the table. Words or numerals should be repeated on successive lines; 'ditto' or ',,' should not be used.

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(31) The correct abbreviation for Tropical Agriculture is *Trop. Agriculture, Trin.*

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